MICHIGAN DEPARTMENT OF TRANSPORTATION
M•DOT

EVALUATION OF SIMULATED BRIDGE DECK SLABS USING UNCOATED, GALVANIZED, AND EPOXY COATED REINFORCING STEEL

MATERIALS and TECHNOLOGY DIVISION

MICHIGAN DEPARTMENT OF TRANSPORTATION
M•DOT

EVALUATION OF SIMULATED BRIDGE DECK SLABS USING UNCOATED, GALVANIZED, AND EPOXY COATED REINFORCING STEEL

R. L. McCrum
C. J. Arnold

A Highway Planning and Research Project by the
Michigan Department of Transportation
in cooperation with the
Federal Highway Administration

Research Laboratory Section
Materials and Technology Division
Research Project 68 F-103
Research Project 73 F-131
Research Report No. R-1320

Lansing, February 1993

This report, authorized by the transportation director, has been prepared to provide technical information and guidance for personnel in the Michigan Department of Transportation, the FHWA, and other reciprocating agencies. The cost of publishing 100 copies of this report at $9.27 per copy is $927.29 and it is printed in accordance with Executive Directive 1991-6.

RECYCLED PAPER

ACTION PLAN

1. Materials and Technology Division

   A. Distribute copies of the report with a cover letter to the Maintenance Division, the Districts, and the FHWA. The cover letter will indicate how this report shows that projected field performance of epoxy coated reinforcement may vary considerably depending on a number of variables including manufacturer, surface preparation of the reinforcement, and quality of the concrete used. The results of this work and the recent controversy over the potential life of epoxy coatings has prompted the initiation of a more accelerated examination of the quality of epoxy coatings that are currently being used by MDOT in new construction.

2. Engineering Operations Committee

   A. No action necessary upon approval of this report.

ABSTRACT

With the advent of a winter bare pavement policy in most northern states during the late 1950s and early 60s, bridge deck deterioration became a much more serious problem. Gradually the main factors causing this deterioration were determined to most likely be salt and water penetration to the level of the top reinforcement. Corrosion of the reinforcement, with the expansive forces generated by the more voluminous corrosion products, and possible freezing of the penetrating water produced a fracture plane just above the top layer of reinforcement.

A number of variables, in addition to increased chloride exposure, were suspected of also playing a role in contributing to bridge deck deterioration. Among these were depth of concrete cover over the reinforcement (i.e., distance that moisture and chlorides would have to penetrate to reach the reinforcement and strength of the force necessary to break the concrete cover) and water/cement ratio (i.e., porosity of the concrete allowing moisture and chloride penetration to greater depths at a faster pace).

Simulated bridge deck slabs containing one-half uncoated steel reinforcement and one-half galvanized reinforcement in the top reinforcement layer, and uncoated steel reinforcement bottom layer, were made with 1/2, 1-1/4, or 2 in. of cover and 6 or 7-1/2 sacks of cement/cu yd and 4-1/2, 5-1/4, or 6 gallons of water/sack of cement (Research Project 68 F-103). A single simulated deck section with 1/2, 1, 1-1/2, 2, 2-1/2, 3, and 3-1/2 in. of cover over both uncoated steel and galvanized steel reinforcement was constructed.

Simulated bridge deck slabs containing epoxy coated, galvanized, or uncoated reinforcement for both top and bottom reinforcement layers were constructed (Research Project 73 F-131). Variables included different types of epoxy, different bar deformation patterns, and different degrees of surface preparation (i.e., commercial, near white, or white sand blast) prior to epoxy coating.

Actual bridge decks were also constructed using uncoated, galvanized, and epoxy coated reinforcement as part of these projects. This work has been reported separately (MDOT Research Report No. R-1321).

Periodic performance evaluation included visual examination, half-cell readings, and chloride penetration measurements. During the last few years of this project, additional measurements were taken. The electric resistance between the top and bottom reinforcement mats was measured (being indicative of the ion transport capability of the concrete and/or condition of the epoxy coating). The macrocell corrosion current between the top and bottom mats (probable performance indicator if top and bottom mats had been electrically connected as can, and typically does, occur) as well as more extensive half-cell measurements. Finally, the slabs were broken up and the extent of corrosion or separation of epoxy coating were evaluated and correlated with other test results.

The results reinforce and extend current knowledge. Thicker cover over the reinforcement results in better protection. Everything else being equal, lower water/cement ratios perform better. Epoxy coated bars and galvanized bars performed better than uncoated bars. Not all epoxy coated bars performed better than galvanized bars when both top and bottom mats were galvanized. The better the surface preparation of an epoxy coated bar the better the performance of the coating. Bars with continuous deformation patterns allowed easier advancement of rusting under the epoxy coating than bars with discontinuous deformation patterns. Problems in the initial experimental design did not allow as valuable a comparison between the performance of galvanized, epoxy coated, and uncoated bars as would be desirable although the galvanized bars were, in general, superior to the uncoated bars and roughly competitive with the epoxy coated bars.

INTRODUCTION AND BACKGROUND

During the 1960s, concrete bridge decks began to deteriorate at an ever increasing rate. A large number of variables were known at the time to adversely affect the construction and performance of concrete bridge decks and many of these factors were initially suspected in contributing to the observed deterioration.

The list includes delayed concrete delivery during placement, adverse weather conditions, and structural vibrations during the finishing and curing periods. Cracking may be caused by restraint to volume change due to shrinkage and temperature, and stringer flexure. In addition, precise control of the depth of concrete cover over the reinforcement is difficult. A plane-of-weakness roughly parallel to the surface was believed to form in the deck at the level of the top reinforcement as a result of entrapment of rising bleed water from the mix. Transverse vertical cracks often formed directly over the transverse reinforcement allowing early infiltration of water and deicing salts. Corrosion and freeze/thaw action in these cracks then contributed to the failure along the plane-of-weakness parallel to the surface and just above the top layer of reinforcement.

In Michigan, a few structures were requiring major repair after only four years of service and many in less than 10 years. From 1960 to 1967, the Department spent over one million dollars for deck repair and replacement on postwar bridges. The average age of these structures at the time of repair was only eleven years. By the early 1970s, deck repair expenses had reached two million dollars per year.

By the early 1960s, the need for understanding and correcting the cause of the problem was evident. Research by a number of states began to pinpoint the most probable causes.

The State Highway Commission of Kansas in cooperation with the Bureau of Public Roads, now the Federal Highway Administration (FHWA), issued a report on bridge deck deterioration in the late 1960s titled, "Weathering Test on Reinforced Concrete Slab with Various Depths of Steel." The slab was cast with a high slump concrete. Uncoated deformed reinforcement was used, with cover over the steel varying from 1/4 in. to 2 in. Formed grooves above each bar accelerated the deterioration effects. There was no live load, and support conditions made the effect of dead load negligible. The slab was subjected to natural climatic conditions, and to periodic application of salt solution to the surface during both warm and cold climatic conditions. Failures were quite similar to those found in Michigan decks. The most important results of this study revealed that:

1) Spalling occurred without live load and with negligible static (i.e., dead) load,

2) Increased concrete cover increased the time required for the appearance of spalls,

3) Increased concrete cover reduced corrosion of the steel, and

4) Scale/spall damage occurred prior to any freezing cycles.

Reports on the durability of bridge decks issued by several state highway departments, including Michigan, done in cooperation with the FHWA and the Portland Cement Association revealed:

1) Correlation existed between spalling and transverse cracking, thin cover over the steel reinforcement, bar corrosion, the amount of chlorides in the concrete at the reinforcement level, location of bar splices, and high water/cement ratios in the deck concrete, and

2) Deterioration did not correlate with the amount of traffic, strength of the deck concrete, or position with respect to positive or negative movement areas of a deck.

It gradually became apparent that the major culprit was corrosion of the reinforcement steel which in turn appeared to be accelerating because of the increased use of chloride deicing salts with the advent of the winter bare pavements policies introduced in northern states during the late 1950s and early 1960s. While salt was apparently the major contributor to deck deterioration, the salt could not be simply eliminated to alleviate the problem. Deicing salt contributed to significant economic and safety benefits that could not be discarded. The solution would have to incorporate measures that could reduce the corrosion damage to the reinforcement by either reducing the amount of salt penetrating to the reinforcement or using reinforcement materials that would not be as susceptible to corrosion.

During the early 1960s, evidence began to surface suggesting that hot-dipped zinc coated reinforcement might provide superior performance to uncoated steel reinforcement.

The American Hot Dip Galvanizers Association began circulating a letter from the Director of Public Works, Bermuda, dated August 14, 1961 concerning an early experiment with galvanized reinforcement. The letter stated that a deteriorated bridge, spanning salt water, was demolished in about 1935, revealing the use of both ungalvanized and galvanized deformed reinforcement in the deck. The ungalvanized reinforcement had rusted sufficiently to crack the concrete, while the galvanized reinforcement had not. The bridge was believed to have been built in the early 1900s.

The International Lead Zinc Research Organization sponsored investigations at the University of California at Berkeley, concerning relative corrosion rates of uncoated and galvanized reinforcement. Concrete specimens constructed with galvanized reinforcement took roughly twice as long to crack as identically prepared specimens with ungalvanized reinforcement exposed to the same corrosive environment.

A bridge deck which might last twice as long while only costing a little bit more was an attractive prospect that provided the incentive for Michigan to investigate the performance of galvanized reinforcement. In 1968, Michigan proposed a study to compare galvanized and uncoated reinforcement that would also evaluate the effect of depth of concrete cover and water/cement ratio. This study, which has been performed in cooperation with the FHWA, is designated as Michigan Research Project 68 F-103.

While this study was in progress, the National Bureau of Standards engaged in contract work for the FHWA concerning the evaluation of more than 40 non-metallic protective coatings that might be suitable for use with reinforcing steel. Results of testing for abrasion durability, flexibility, impact resistance, permeability to chlorides, bond to steel, bond to concrete, resistance to various other liquid chemicals, and creep under load, revealed four candidates that might provide suitable service. These coatings, being electrically non-conducting, provided even greater promise of potential service life. While galvanizing would corrode and possibly eventually result in similar corrosion product expansion problems that result in failures with uncoated reinforcement, the epoxy coatings, providing that they remain intact, might totally or almost totally prevent corrosion from occurring. In 1973, Michigan proposed a study of the two coatings that were sufficiently fast curing to lend themselves to the high production speeds necessary for a commercial coating operation (a third coating met the necessary requirements prior to the implementation of the project and was added). This study, which has been performed in cooperation with the FHWA, has compared the performance of epoxy coated reinforcement with that of uncoated and galvanized reinforcement and compared the performance of the same epoxy with different levels of surface preparation. This study is designated as Michigan Research Project 73 F-131.

Both studies have examined reinforcement performance for small laboratory specimens, simulated bridge deck slabs (3 ft by 4 ft by 7-1/2 in.) in real world environments (i.e., field specimens), and actual bridge decks. This report examines only the performance of the simulated bridge deck slabs/field specimens; the other work involved in these projects has been reported separately. The work with full size bridge decks is available as Michigan Research Report R-1321.

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration or the Michigan Department of Transportation. This report does not constitute a standard, specification, or regulation.

Scope

Galvanized (68 F-103)

In this project, 29 test slabs simulating a small portion of a bridge deck (3 ft by 4 ft by 7-1/2 in.) were cast in the laboratory and exposed to an outdoor (i.e., field) environment. Typical size reinforcing bars were embedded in each slab. One-half of the bars in the top mat were galvanized while the bars in the other half were uncoated steel. Side-by-side bar splices were included in the top mat in some specimens. Bottom mat reinforcement was all uncoated steel. Since the bars were supported by wooden forms when the specimens were cast, there was no direct internal electrical contact between the top and bottom mats.

The clear cover over the bars and the concrete mix design were modified to study how these variables affect the performance of uncoated and galvanized steel bars in a salted concrete environment. Slabs were cured with polyethylene film for seven days, then air dried until placement in the field.

A large simulated concrete deck (slabs 30 through 36) was cast for the 68 F-103 project. Both galvanized and uncoated bars were used, as with the slabs, while the clear cover over the bars was varied. A full size bridge beam added restraint to shrinkage. A high slump concrete mix was used, surface drying was allowed and the curing application was delayed to facilitate shrinkage and cracking of the simulated deck. These adverse conditions, purposely applied, were made to help accelerate deterioration of the simulated deck. Dikes were built around the edges of the test slabs and the simulated deck to retain water, the concrete surfaces were then salted on a regular basis during the winter months.

Periodic observations and measurements were made to provide as objective a comparative evaluation of the different treatments as possible.

Epoxy Coated (73 F-131)

In this project, 38 simulated bridge deck slabs (3 ft by 4 ft by 7-1/2 in.) were cast using uncoated, galvanized, or epoxy coated reinforcement.

Three different epoxy coatings were used with three different surface preparations for each type of epoxy coating. In general the same coating treatment was used for the steel reinforcement in both the top and bottom mats. Several slabs, however, did have galvanized reinforcement in the top mat with uncoated reinforcement in the bottom mat. The same concrete mix and clear cover were used for all of these test specimens.

Dikes were built around the edges of the test slabs to retain water, the concrete surfaces were salted on a regular basis during the winter months, and periodic observations and measurements were made as on 68 F-103.

Objectives

Galvanized (68 F-103)

1) To determine what effect increased clear cover and concrete mix design (i.e., water/cement ratio, cement content, etc.) have on the relative corrosion and deterioration rates of concrete bridge decks, and

2) To determine the feasibility of using galvanized reinforcement in constructing Michigan Department of Transportation bridge decks.

Epoxy Coated (73 F-131)

1) To determine what effect surface preparation (i.e., commerical blast, near white metal blast, white metal blast, etc.) has on the performance of epoxy coated steel reinforcement,

2) To compare the performance of different types of epoxy coated reinforcement and compare this performance to that of uncoated and galvanized reinforcement, and

3) To determine the feasibility of using epoxy coated reinforcement in constructing Michigan Department of Transportation bridge decks.

Procedure

Galvanized (68 F-103)

Twenty-nine 3 ft by 4 ft by 7-1/2 in. field exposure slabs were cast in the laboratory. One-half of the steel in the top mat of each specimen was galvanized with a nominal 1-1/2 oz/sq ft coating. Concrete mixes consisted of 6AA aggregate with 6 or 7 sacks/cu yd of cement, and 4-1/2, 5-1/4, or 6 gal of water/sack of cement. Concrete cover over the bars was either 1/2, 1-1/4, or 2 in. Specimens were cured with polyethylene for seven days, then air cured for a minimum of 21 days before placement in the field. The slabs were exposed to natural weather conditions plus weekly applications of salt during cold weather (December through March). Specification for galvanizing on the field exposure specimens called for 1-1/2 oz/sq ft average, with a minimum of 1 oz/sq ft. The average coating thickness (274 readings) was 2.6 oz/sq ft with a range from 0.6 to 5.9 oz/sq ft.

The slabs were cast in wooden forms in the laboratory (Fig. 1). Holes drilled in the forms at the proper distance from the top controlled the amount of cover over the bars, and also held the bars firmly in place during subsidence and curing of the concrete.

Slab Nos. 1 through 22 had three galvanized and three uncoated No. 6 reinforcing steel bars on 8-in. centers in the primary (transverse) steel of the top mat. Two galvanized No. 4 bars make up the longitudinal portion of the top mat and are placed below the larger transverse bars. The bottom mat is identical except all reinforcing steel bars are ungalvanized and longitudinal bars are No. 5. Slab Nos. 23 through 25 had no galvanized steel, and had one-half of the slab surface treated with linseed oil and mineral spirits. In slab Nos. 26 through 29, all of the bars in the top mat were galvanized and three No. 6 bars in each specimen were given an additional surface treatment with potassium dichromate.

Along with these slabs, a simulated composite deck section, 30 ft long by 5 ft wide by 7-1/2 in. thick was cast on a 36-in. wide-flange beam in the field (Fig. 2). Galvanized and ungalvanized bars were used in the top mat with the coating thickness as noted above; concrete cover varies from 1/2 to 3-1/2 in. in 1/2-in. increments. The beam specimen was cast with a wet mix, subjected to surface drying, delayed application of curing, and early application of salt, to promote shrinkage cracking and early deterioration of the slab. Again, weekly applications of salt were made during winter weather.

Water retaining dikes were added to all individual slabs and the composite deck section to allow ponding of a concentrated solution of sodium chloride during the winter months. Salt residue was washed from the surface by rain water during warmer months.

Periodic evaluation of the slabs included several techniques. Visual inspection was made for indications of deterioration, such as vertical cracking over the reinforcement, and rust staining. Half-cell measurements were taken. Soundings for delaminations were made. During the last several years of the project some additional evaluation techniques were employed. More extensive half-cell measurements were taken—readings were taken of both the top and bottom mats with and without top and bottom mats shorted. Macrocell corrosion current between top and bottom mats was recorded using a zero-resistance ammeter. To allow separate measures of the top/bottom mat macrocell current for the galvanized and uncoated bars, the longitudinal reinforcement linking the top mat bars was severed by coring between the galvanized and uncoated

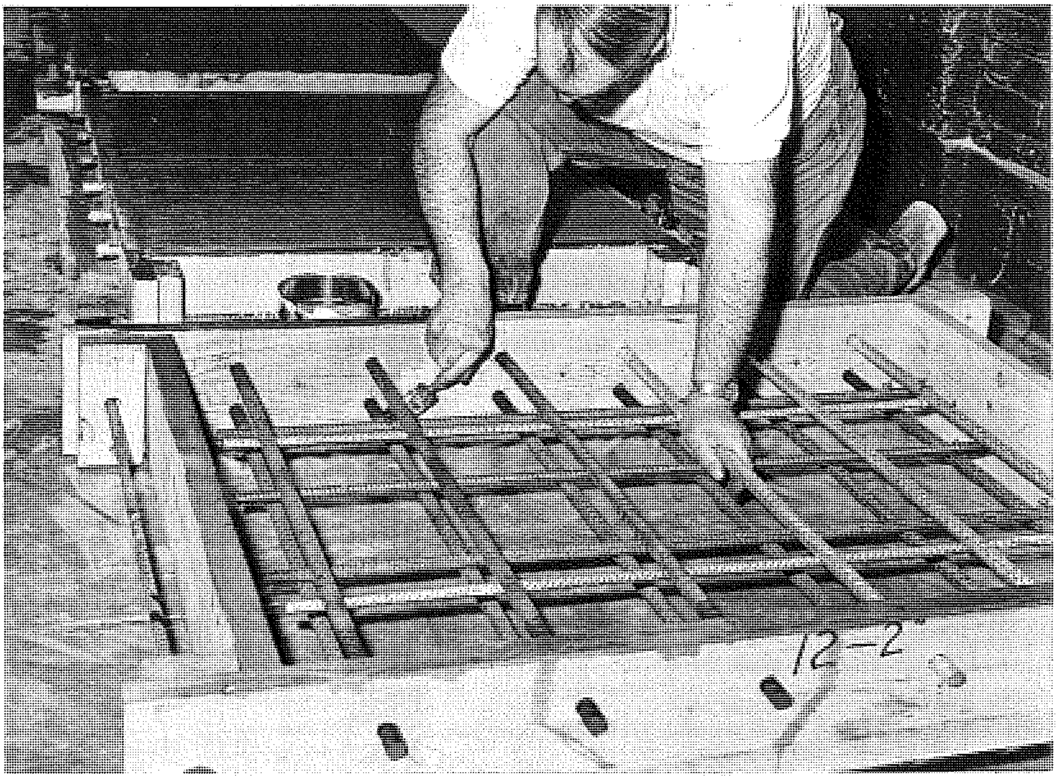


Figure 1. Slab form in preparation for casting. Note three galvanized No. 6 bars in top mat at right, and two galvanized No. 4 bars as longitudinal steel. Bottom mat of No. 5 and No. 6 bars, all ungalvanized.

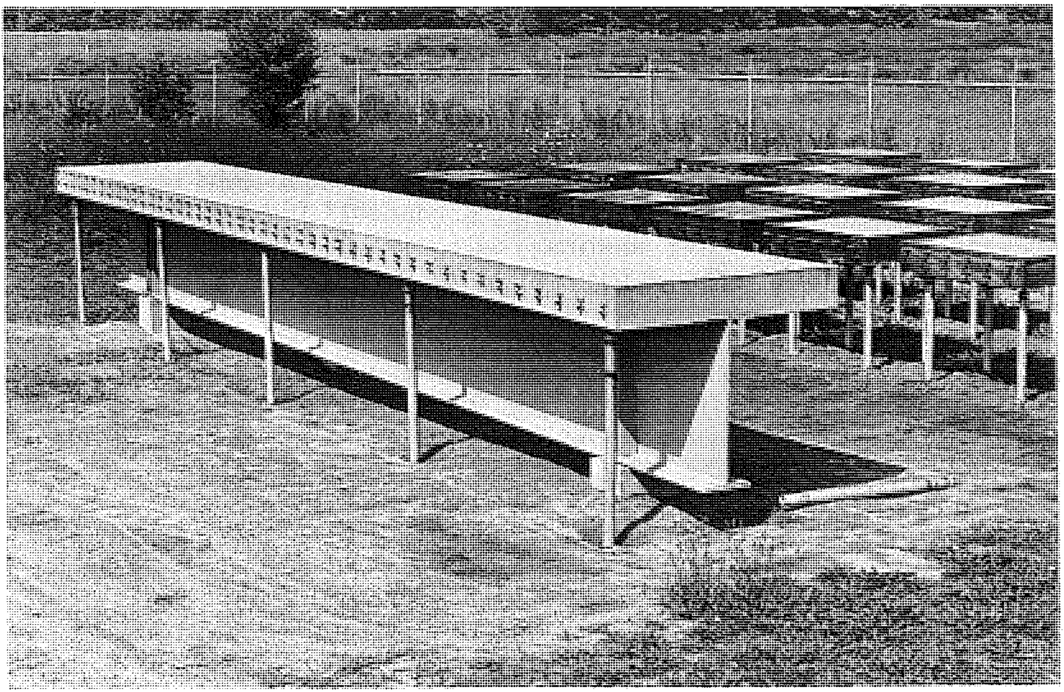


Figure 2. Field installation of laboratory cast deck specimens and simulated deck section (Galvanized--68 F-103). Water retaining dikes were added to the larger section at a later date.

sides of the slabs in 1986. Electrical resistance measurements were taken of the concrete between the top and bottom mats.

Following conclusion of the project after 17 years of field exposure, the slabs were demolished and the reinforcement examined for evidence of corrosion. The approximate surface areas of corrosion for individual bars and slabs were recorded.

Epoxy Coated (73 F-131)

Coating flexibility was evaluated by bending representative bars through 120° over a wooden mandrel with a 3-in. radius. Five specimens of each type were bent soon after the bars were coated, five specimens were bent after three months outdoor exposure, and five more specimens were bent after one year of storage in the Laboratory.

Thirty-eight simulated deck specimens similar to those used in 68 F-103 were cast in the field. Specimen size was approximately 3 ft by 4 ft by 7-1/2 in. with typical bridge deck reinforcement cast in each one. Reinforcement included six No. 6 steel bars in the main transverse portion of both the top and bottom mats, with No. 4 and No. 5 longitudinal bars in the top and bottom, respectively. All specimens were cast with 6-sack ready-mix (i.e., standard bridge deck concrete at the time the specimens were made), using 1-1/4-in. concrete cover over the top bars.

Triplicate specimens were cast with the three epoxy coatings, and three blast treatments as separate entries (a total of 27 specimens). In addition, galvanized bars were added in six specimens, three with all bars galvanized and three with galvanized bars in the top mat only. Three specimens were cast with white metal blast 3M coating, and uncoated bar chairs, and two specimens were prepared with all bars uncoated.

The field exposure specimens were constructed on site in the fall of 1974. Water retaining dikes were built on the specimens, and weekly treatment with salt was applied during winter months.

Periodic evaluations were made following the same procedures and time table as those for 68 F-103. Following conclusion of the project after 13 years of field exposure, the slabs were demolished and the reinforcement examined for evidence of corrosion and the integrity of the epoxy and zinc coatings. The approximate surface areas of corrosion/debonded epoxy coating were recorded for individual bars and slabs.

RESULTS AND DISCUSSION

Some previous results have been reported for both projects, these are summarized here, as necessary, to allow complete examination of the results without referring to a number of different reports.

TABLE 1
INITIAL DATA FOR GALVANIZED FIELD EXPOSURE SPECIMENS

Slab No.	Cover, in.	Bars Spliced	Concrete Design		Air Content, percent	Slump, in.	28-Day Compressive Strength, psi.
			Cement, sacks/cu yd	Water, gal/sack			
1	1-1/4	No	7-1/2	4-1/2	5.4	2-3/8	5530
2	2	No	6	5-1/4	7.6	4-1/8	3760
3	1/2	No	7-1/2	4-1/2	5.7	3-1/2	4580
4	2	No	6	5-1/4	7.4	5-1/2	3810
5	1/2	Yes	6	5-1/4	5.5	3	4810
6	1-1/4	No	6	5-1/4	6.1	2-7/8	3310
7	1-1/4	No	6	6	5.6	7-1/2	3950
8	2	Yes	6	5-1/4	7.7	3-7/8	3440
9	2	Yes	6	5-1/4	7.5	4-1/2	4400
10	1/2	No	6	5-1/4	5.9	2-1/8	4080
11	1-1/4	Yes	6	5-1/4	6.7	3-1/2	4540
12	2	No	6	6	7.0	8-3/8	3420
13	1/2	No	7-1/2	4-1/2	5.3	1-7/8	5080
14	1/2	No	6	6	7.4	7-1/8	3960
15	1-1/4	No	6	5-1/4	4.1	1-1/2	4740
16	1/2	No	6	6	5.8	7	4200
17	1/2	No	6	5-1/4	5.1	2-1/8	4380
18	2	No	6	5-1/4	5.2	2-3/8	4520
19	1-1/4	No	6	6	4.8	7-1/8	3950
20	1-1/4	Yes	6	5-1/4	4.2	1-7/8	5140
21	1/2	Yes	6	5-1/4	5.9	4-1/4	4390
22	1-1/4	No	6	6	12.4	7-1/8	2650
Field Beam[1]							
<u>Section</u>							
30	1/2	Yes	6	5+	5.8	5-1/4[2]	2920
31	1	No	6	5+			
32	1-1/2	No	6	5+			
33	2	No	6	5+			
34	2-1/2	No	6	5+			
35	3	No	6	5+			
36	3-1/2	No	6	5+			

---

[1] Field Beam (4 ft, 7-1/2 in. by 36 ft by 7-1/2 in. on 36-in. WF 150 beam with shear developers).
[2] After 15 mile haul in ready mix truck.

Performance results have been measured in a number of ways, each of which is reported separately and then correlated with the other measurement methods. The most valuable information is the final condition of the reinforcement (i.e., amount of rusting--surface covered and volume of rust produced). This should, in general, correlate quite well with the observed condition of the deck slabs barring problems with the concrete which may affect the performance of the concrete independent of rusting of the reinforcement. Next in importance is the final condition of simulated bridge deck slabs (as determined by visual observation and sounding). The other methods of measurement employed (i.e., half-cell measurements, and macrocell corrosion current and electrical resistance between the top and bottom mats) are typically valuable only to the extent that they can help to predict the eventual condition of the simulated decks and their steel reinforcement (preferably before it becomes visually obvious). For both of the projects covered in this report, where the top and bottom mats are electrically isolated, the macrocell corrosion currents should be more indicative of what might have been if the mats were electrically 'shorted' than a reflection of their actual 'isolated' performance.

A computer program was written for helping to make equipotential plots and cumulative frequency distribution plots (satisfies the information requirements of ASTM C 876). While this program was originally written for handling the experimental bridge decks included in these projects, it can be readily adapted to handle the experimental bridge deck slabs as well as other physical configurations. The program, as used in MS-DOS FORTRAN, is listed in Appendix A with sample input and output.

A zero-resistance ammeter used for making current measurements between the top and bottom reinforcement mats was built by making minor modifications to a device proposed by Lauer and Mansfield. Circuit drawings for this device are given in Appendix B.

Galvanized (68 F-103)

Initial Details

Table 1 summarizes the variables that most probably influence the performance of the field specimens. Galvanizing thicknesses of the individual bars are recorded in Appendix C.

Slabs 23 through 25 (all uncoated bars), which had half of the slab surface treated with linseed oil and mineral spirits, and slabs 26 through 29 (all galvanized bars), which were treated with potassium dichromate for half of the top mat, did not perform well and were abandoned after only several years of exposure. Concrete deterioration rather than bar corrosion was regarded as the primary problem for these slabs.

Visual Observation

Visual observations were made of the simulated slabs on a periodic basis during the course of the project. Observed performance (as mea-

TABLE 2
VISUALLY DETECTED DETERIORATION OF GALVANIZED FIELD SPECIMENS AFTER SIX AND FOURTEEN YEARS OF EXPOSURE

Experimental Details			Rating of Specimens (After Six Winters)				Rating of Specimens (After Fourteen Winters)**			
			Uncoated Bars		Galvanized Bars		Uncoated Bars		Galvanized Bars	
Concrete Cover	Cement sacks/cu yd	Water, gal/sack	Open Crack, lin in.	Popouts, sq in.	Open Cracks, lin in.	Popouts, sq in.	Open Cracks, lin in.	Popouts, sq in.	Open Cracks, lin in.	Popouts, sq in.
1/2**	6	6	54	13	20	8	76	23	33	15
	6*	5-1/4	29	13	15	3	58	33	23	16
	6	5-1/4	77	29	16	6	90	38	25	22
	7-1/2	4-1/2	48	15	22	22	48	14	22	22
1-1/4	6	6	20	9	26	1	72	10	76	1
	6*	5-1/4	24	2	22	0	76	5	91	8
	6	5-1/4	18	0	0	0	84	6	54	0
	7-1/2	4-1/2	15	5	0	0	60	18	0	0
2	6	6	12	6	6	2	24	4	34	2
	6*	5-1/4	24	3	16	1	22	3	16	1
	6	5-1/4	0	0	12	0	0	0	0	0
Simulated Deck Section										
1/2	6*	5+	33	8	--	--	33	8	--	--
1/2	6	5+	50	12	4	6	56	53	23	24
1	6	5+	0	0	12	0	72	12	27	0
1-1/2	6	5+	0	1	0	0	18	1	36	0
2	6	5+	0	0	0	0	0	0	16	0
2-1/2	6	5+	0	1	0	3	0	1	0	3
3	6	5+	0	0	0	0	0	0	0	0
3-1/2	6	5+	0	3	0	1	0	3	0	1

* Bar splices present

** Eleven years for specimens with 1/2-in. depth of cover sured by cracking and spall/scaling/popout) are recorded in Table 2 after six and fourteen years of exposure. Since the visual observations were not always consistent (variations occurred depending on who examined the specimens and the weather conditions at the time of the examination, e.g., cracks show up better when damp) Table 2 reflects the worst cases observed during six and fourteen years of exposure, respectively. Appendix D contains a complete record of all recorded visual observations.

While there has been some overlap of the results, the general trend of the data shows better performance for thicker cover depths and lower water/cement ratios. The combination of 1-1/4 in. depth of cover with a 7-1/2 sacks of cement/cu yd and 4-1/2 gal/sack mix appears to be particularly beneficial for the galvanized portions of the slabs. There are insufficient numbers of replicate specimens, however, to ensure that this is not just an anomaly in the data.

The galvanized portions of the slabs do not show as great a degree of deterioration as the uncoated portions although the differences are not, in general, quite as dramatic after fourteen years as they were after six years. That a difference exists at all is very significant since the manner in which the reinforcing steel was placed (Fig. 1), with longitudinal galvanized reinforcement effectively linking the uncoated and galvanized transverse reinforcement, allows the zinc coating to be galvanically sacrificial to at least some of the uncoated reinforcement. In other words the galvanized reinforcement should be oxidizing, to some extent, faster and the uncoated reinforcement, to some extent, slower because of this linkage making it more difficult to interpret correctly the relative performance of the uncoated and galvanized bars. The implication is that the galvanized reinforcement, by itself, would probably perform better than is indicated here and the uncoated reinforcement worse. The longitudinal linkage on the top mat was severed in 1986 but this did not eliminate the galvanizing on the portions of the longitudinal bars still remaining on the uncoated side and could not reverse the effects of the previous sixteen years of 'linked' corrosion.

Pictures were taken during the Fall of 1976; these are shown in Figure 3. The photos have been rearranged from their sequential order to show the variation in performance that results from the variation of the different parameters investigated. Photos are ordered according to increasing depth of cover and decreasing water/cement ratio. Specimens 14, 16, 5, 21, 10, 17, 3, and 13 have 1/2-in. depth of cover. Specimens 7, 19, 22, 11, 20, 6, 15, and 1 have a 1-1/4-in. depth of cover. Specimens 12, 8, 9, 2, 4, and 18 have a 2-in. depth of cover. Specimens within each depth of cover grouping have been listed in order of decreasing water/cement ratio. Specimens 30 through 36 all have the same water/cement ratio and are presented in order of increasing depth of cover. Specimens 5, 8, 9, 11, 20, 21, and 30 have splices in the reinforcement. In Figure 3, the galvanized bars are on the right side and the uncoated bars are on the left.

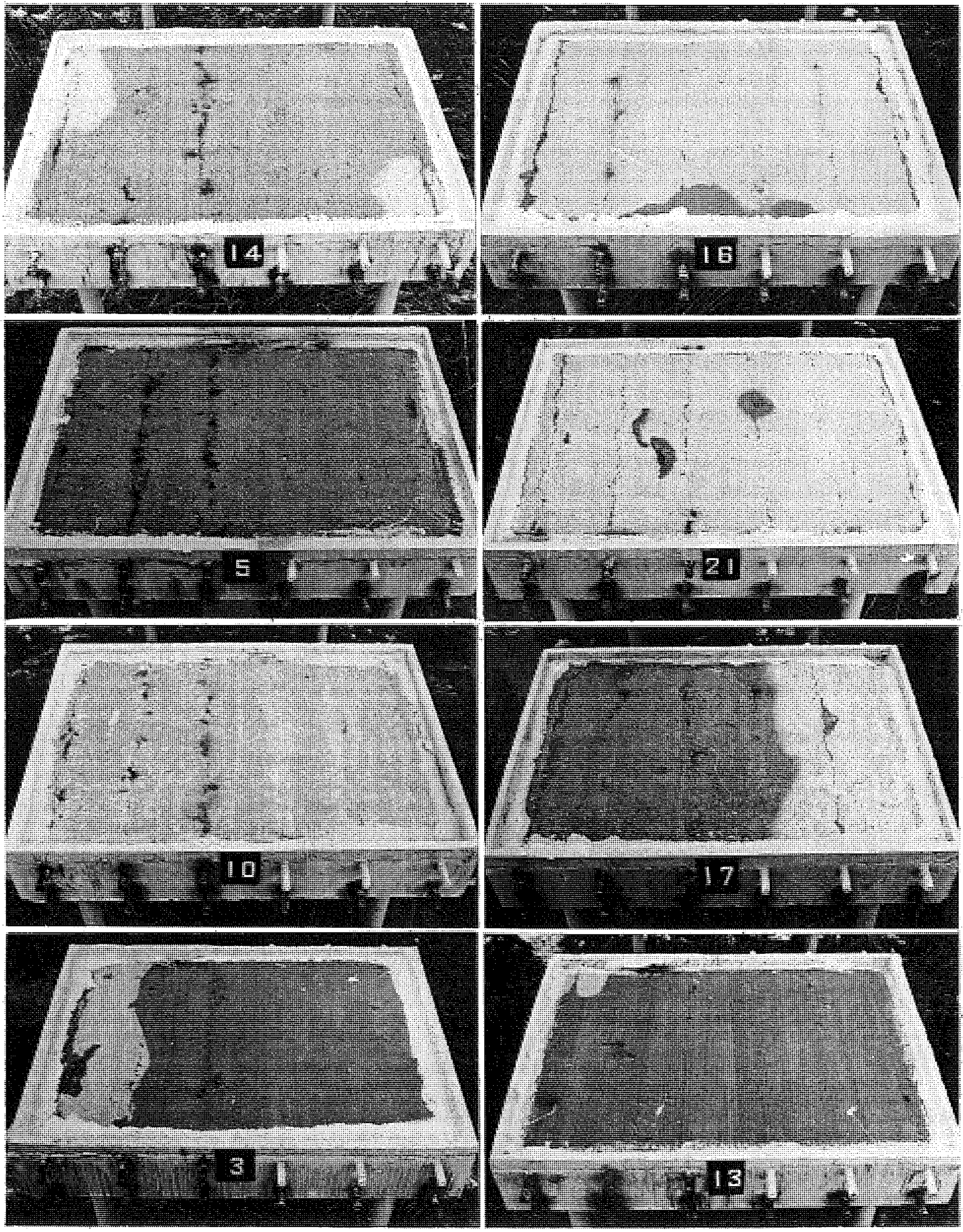


Figure 3. Appearance of galvanized field exposure specimens after six years of exposure. One-half inch depth of cover specimens presented in order of decreasing water/cement ratio (left to right and top to bottom).

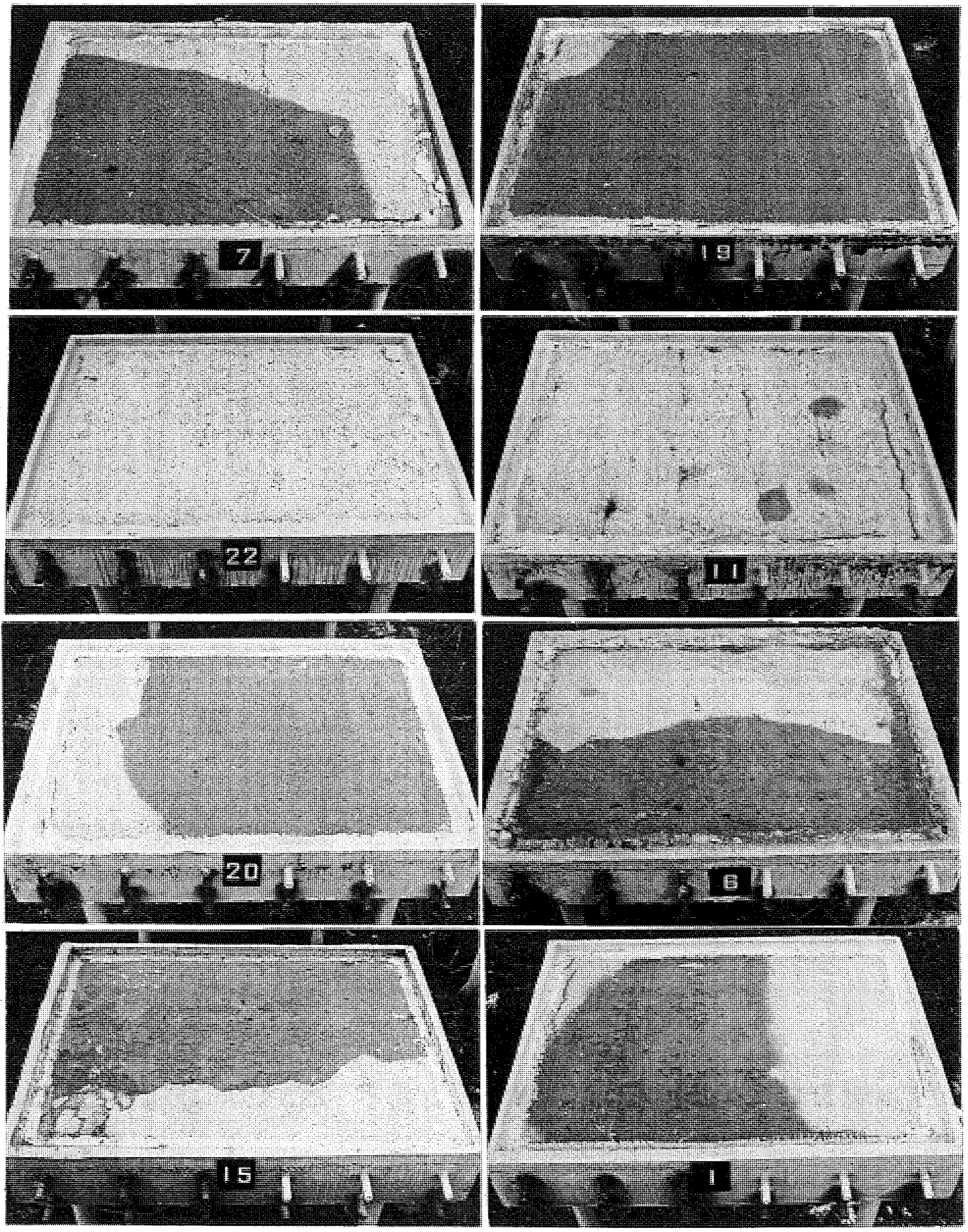


Figure 3 Continued. Appearance of galvanized field exposure specimens after six years of exposure. One-quarter inch depth of cover specimens presented in order of decreasing water/cement ratio (left to right and top to bottom).

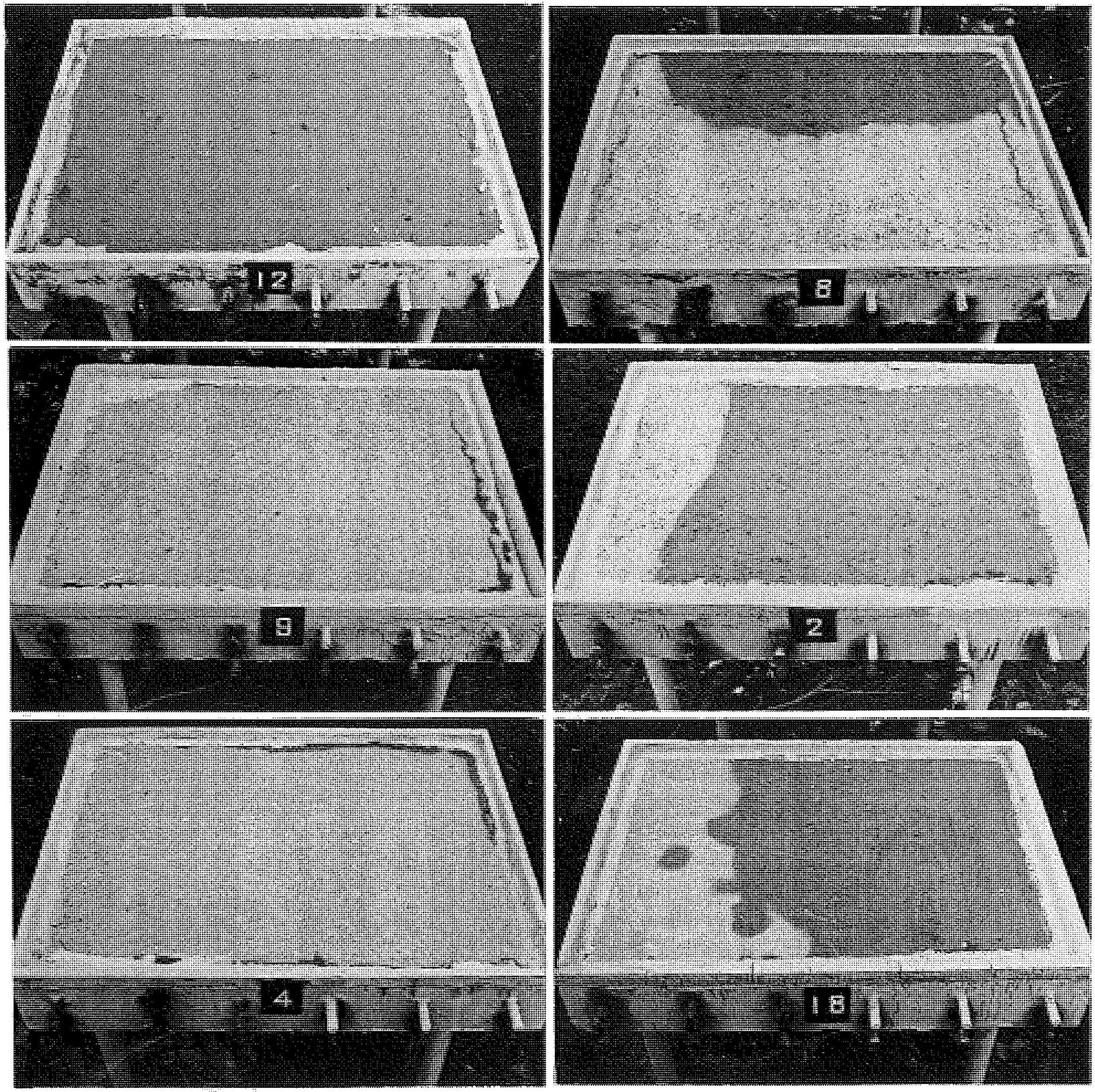


Figure 3 Continued. Appearance of galvanized field exposure specimens after six years of exposure. Two-inch depth of cover specimens presented in order of decreasing water/cement ratio (left to right and top to bottom).

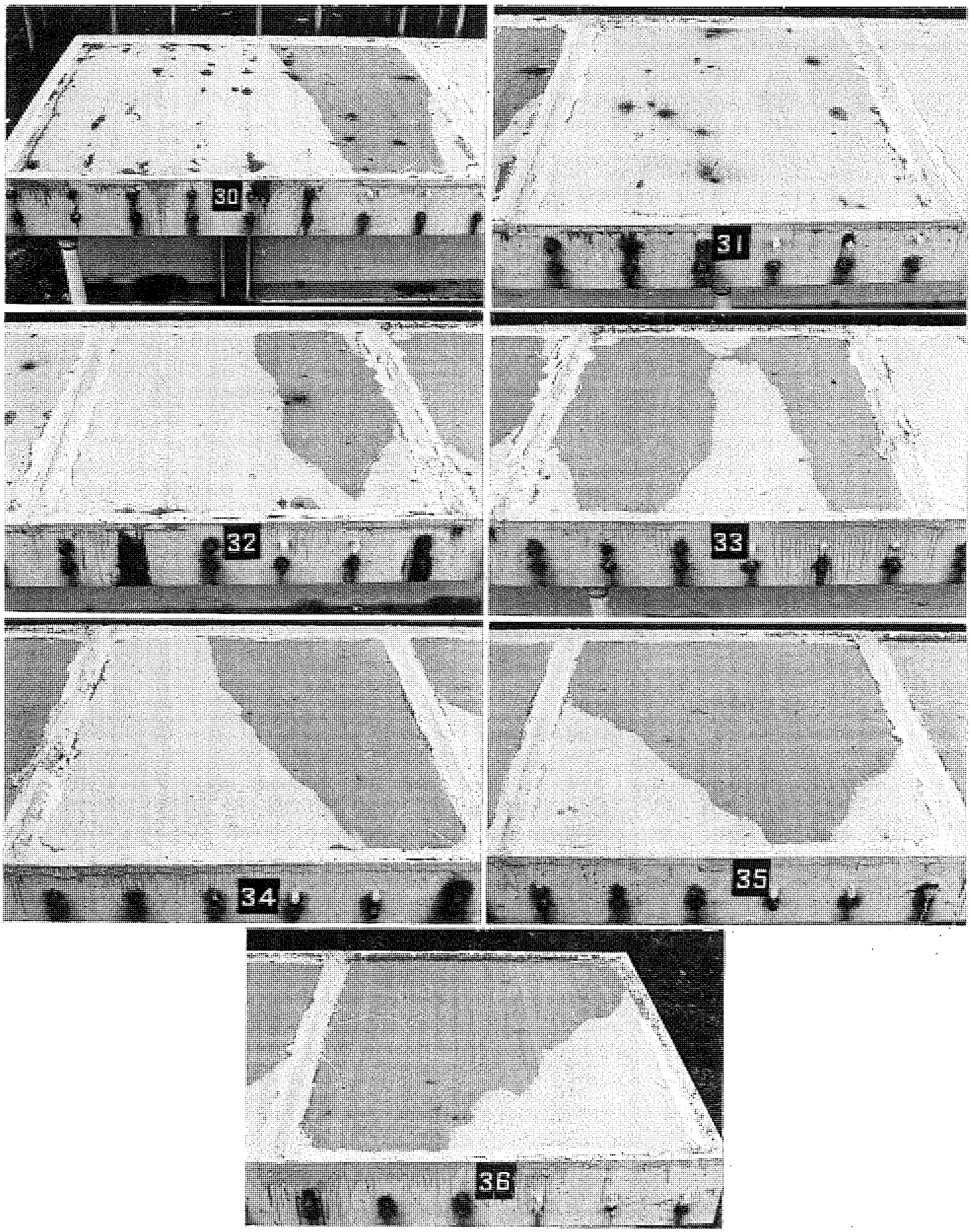


Figure 3 Continued. Appearance of galvanized field exposure specimens after six years of exposure. Simulated bridge deck slab specimens presented in order of increasing depth of cover (left to right and top to bottom).

For 1/2-in. depth of cover, the visual results are very dramatic. Cracking is universally present over the uncoated portion of the top mat and only sporadically present over the galvanized portion. Improved performance is evident for the lower water/cement ratios.

For 1-1/4-in. depth of cover, cracking is roughly equally divided between the uncoated and the galvanized sides. The worst cracking occurs for slab 11, one of the slabs with bar splices. No major difference is evident for lower water/cement ratios.

For 2-in. depth of cover, the only visible deterioration is some cracking over the end bars with the remainder of the deck surface looking fairly good. The cracking over the end bars is roughly equally divided between the galvanized and uncoated portions of the deck. This end bar cracking is probably not a good indicator of specimen performance since the shortened longitudinal bars under these transverse bars do not provide the same support as would occur in a real deck, and cracking probably proceeds in these areas to a greater extent and at a more rapid pace than would ever occur in a real deck. The center portions of these simulated decks should be more representative of real decks and, therefore, the area of interest in evaluating specimen performance.

For the simulated bridge deck (i.e., specimens 30 through 36) numerous popouts are evident over the transverse reinforcement with only 1/2-in. and 1-in. depths of cover. The remainder of the deck looks fairly good. Popouts are slightly more prevalent over the uncoated portions of the deck.

Photos were again taken during the Fall of 1987 at the conclusion of the project. The slabs are again reordered to better highlight any performance variations that have resulted from the variation of the different parameters examined (Fig.4—specimen ordering follows the same pattern as used for Fig. 3 except that the 1/2-in. depth of cover specimens no longer existed when these pictures were taken). Several photos were taken of each slab to better show slab deterioration. In the first photo for each slab, the galvanized portion of the slab is on the left and the uncoated portion on the right.

For the 1-1/4-in. depth of cover specimens with six sacks of cement/cu yd and six gal/water/sack of cement, the extent of deterioration appears to be roughly equal between the uncoated and galvanized portions of the deck, the galvanized portions being in worse shape on some individual slabs.

For the 1-1/4-in. depth of cover specimens with six sacks of cement/cu yd and 5-1/4 gal/water/sack of cement, the extent of deterioration again appears to be roughly equal between the two sides.

For the 1-1/4-in. depth of cover specimens with seven sacks of cement/cu yd and 4-1/2 gal/water/sack of cement, almost all visible damage is on the uncoated side of the slab.

For the 2-in. depth of cover specimens with six sacks of cement/cu yd and six gal/water/sack of cement, visible deterioration is primarily on the uncoated side of the slab.

For the 2-in. depth of cover specimens with six sacks of cement/cu yd and 5-1/4 gal/water/sack of cement, visible damage is roughly equally divided between the galvanized and uncoated sides of the slabs. Some individual slabs have more damage on the galvanized side and some on the uncoated side.

For the simulated bridge deck (i.e., specimens 31 through 36) numerous popouts are evident over the transverse reinforcement with only 1-in. depth of cover. The remainder of the deck looks fairly good with only sporadic popouts.

Poor performance over the galvanized reinforcement occurred more frequently in slabs with very high (i.e., greater than 5-1/4 in.) and very low slumps (i.e., less than 2 in.).

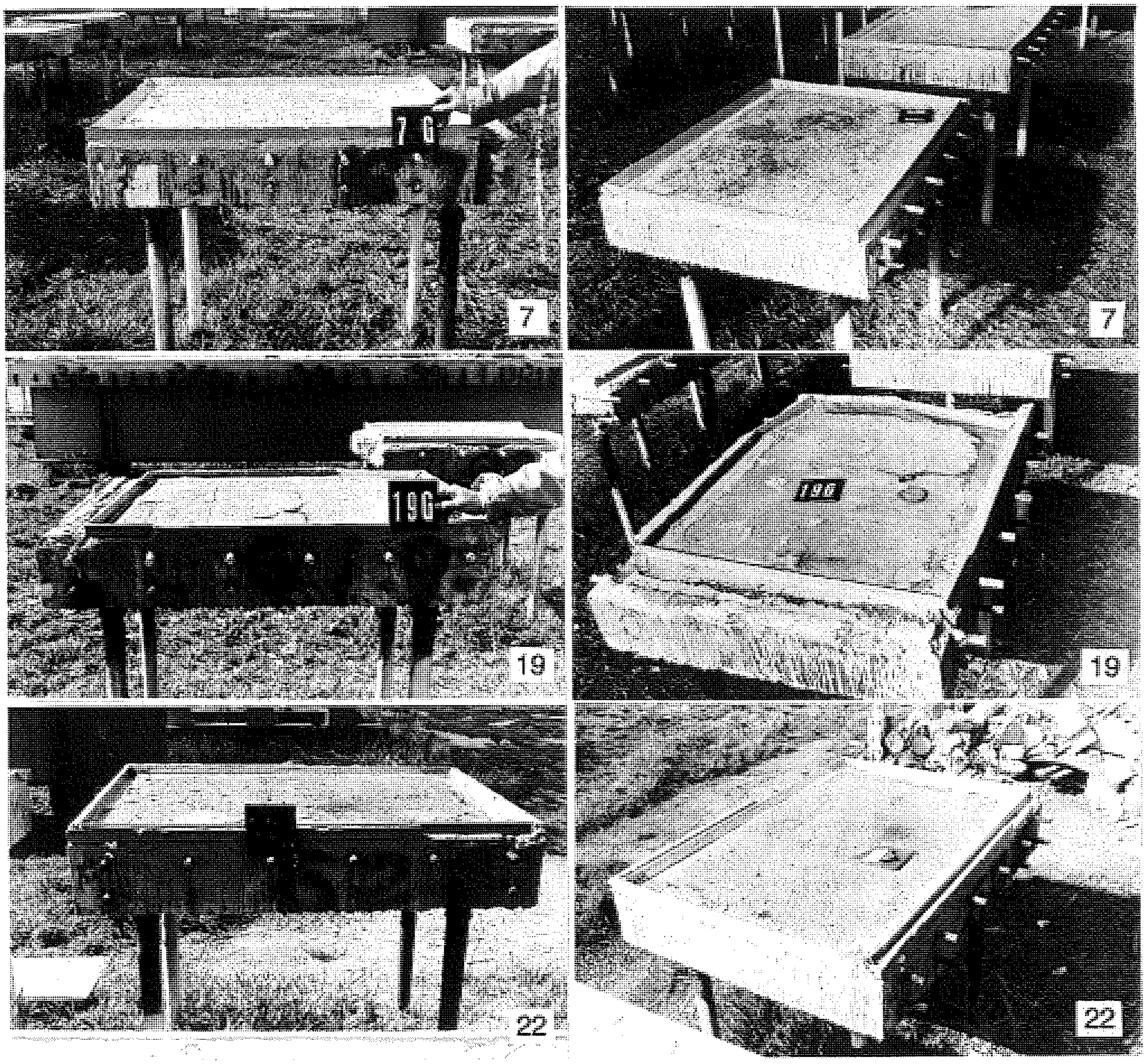


Figure 4. Appearance of galvanized field exposure specimens after 17 years of exposure. One and one-quarter inch depth of cover specimens with six sacks of cement/cu yd and six gallons of water/sack of cement.

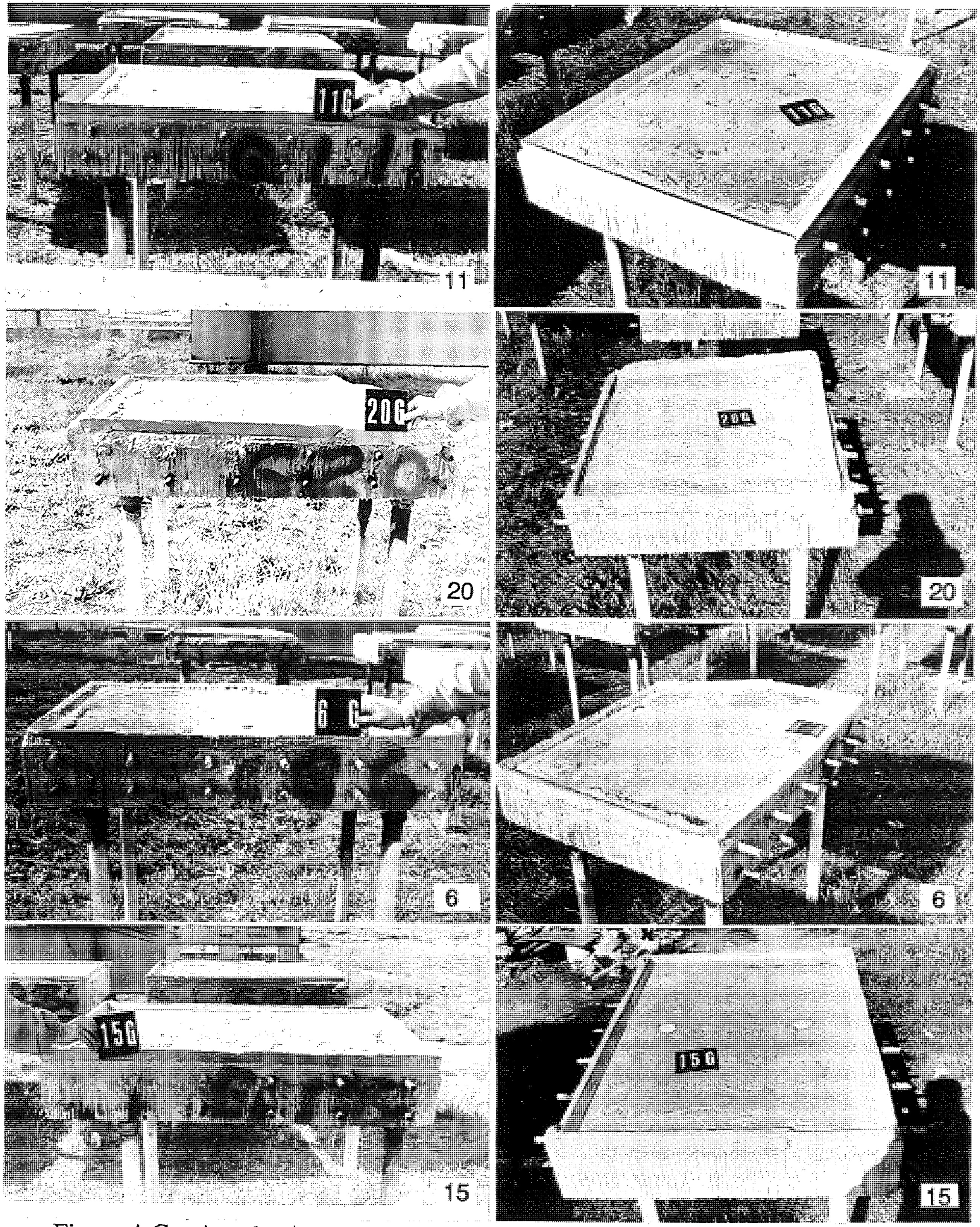


Figure 4 Continued. Appearance of galvanized field exposure specimens after 17 years of exposure. One and one-quarter inch depth of cover specimens with six sacks of cement/cu yd and five and one-quarter gallons of water/sack of cement.

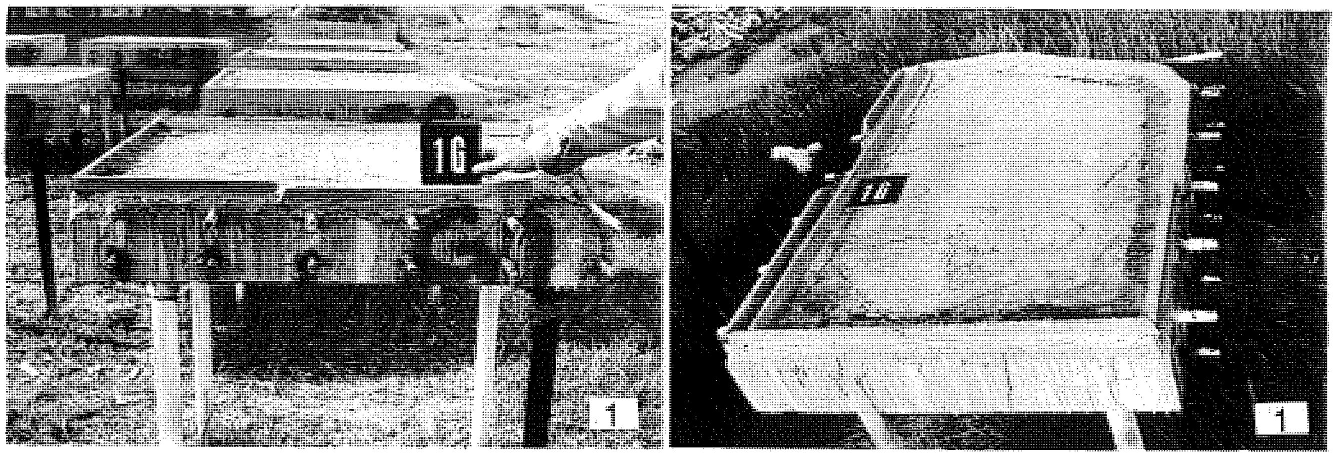


Figure 4 Continued. Appearance of galvanized field exposure specimens after 17 years of exposure. One and one-quarter inch depth of cover specimens with seven sacks of cement/cu yd and four and one-half gallons of water/sack of cement.

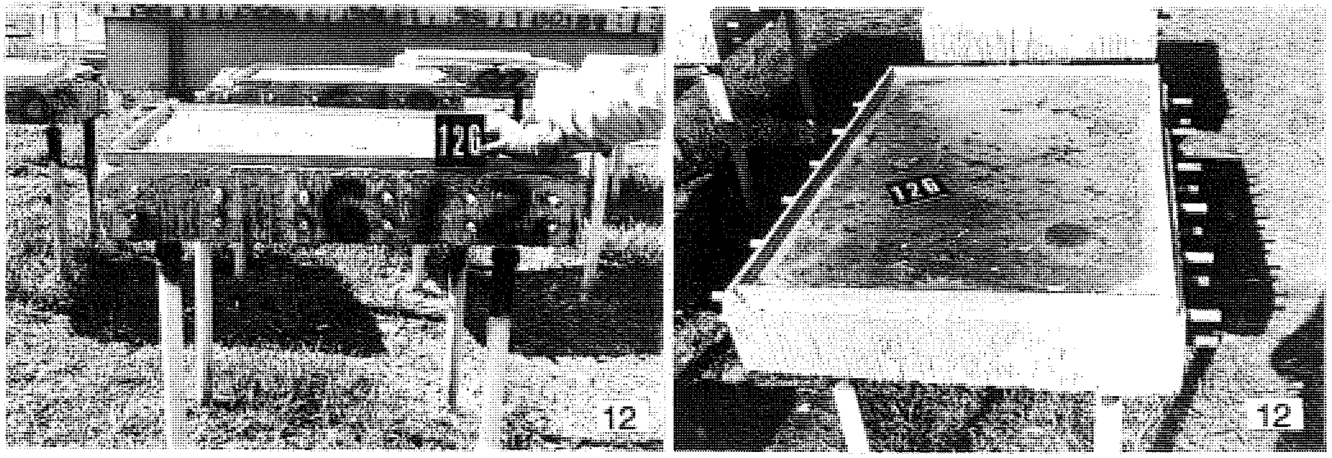


Figure 4 Continued. Appearance of galvanized field exposure specimens after 17 years of exposure. Two-inch depth of cover specimens with six sacks of cement/cu yd and six gallons of water/sack of cement.

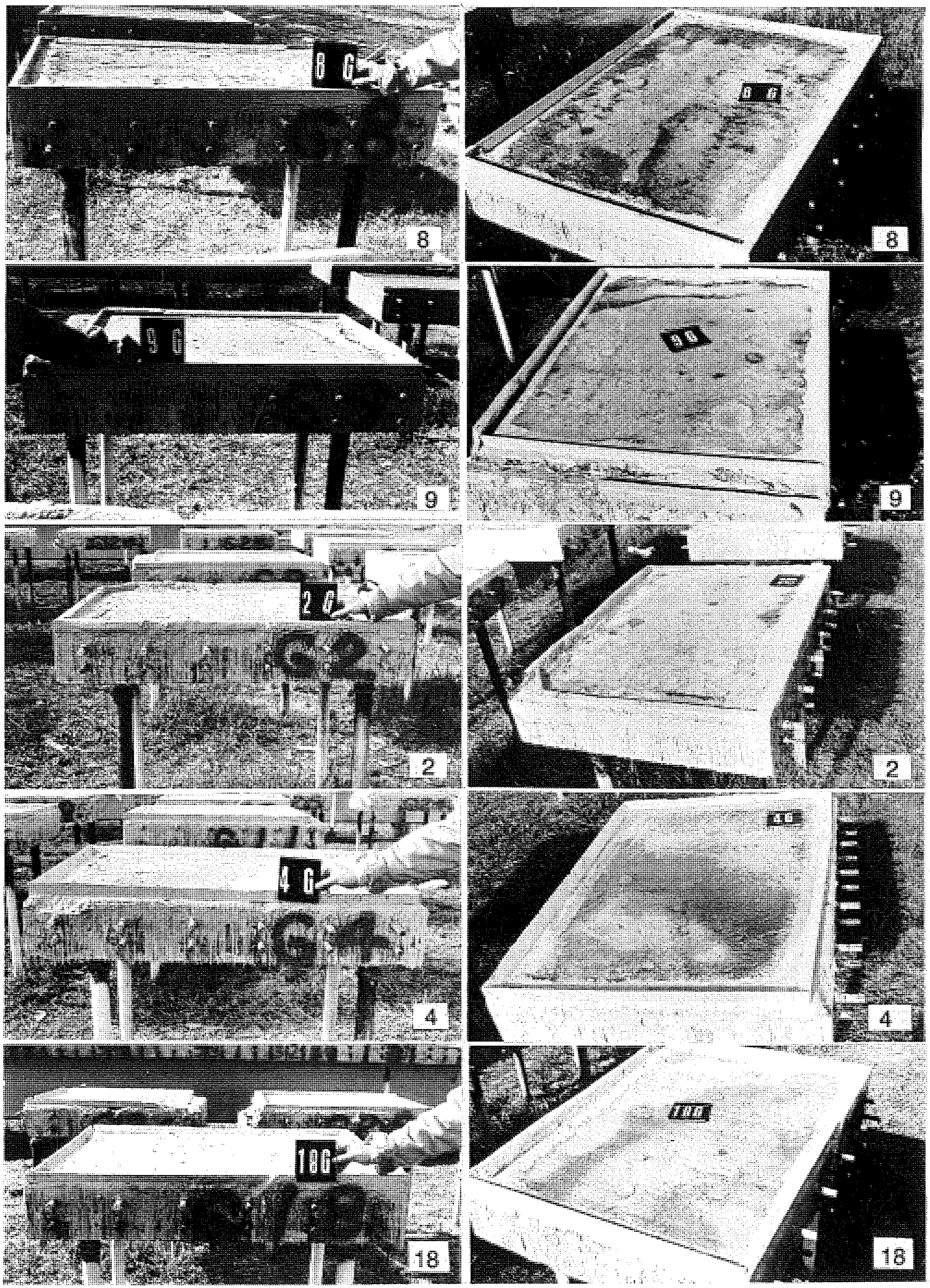


Figure 4 Continued. Appearance of galvanized field exposure specimens after 17 years of exposure. Two-inch depth of cover specimens with six sacks of cement/cu yd and five and one-quarter gallons of water/sack of cement.

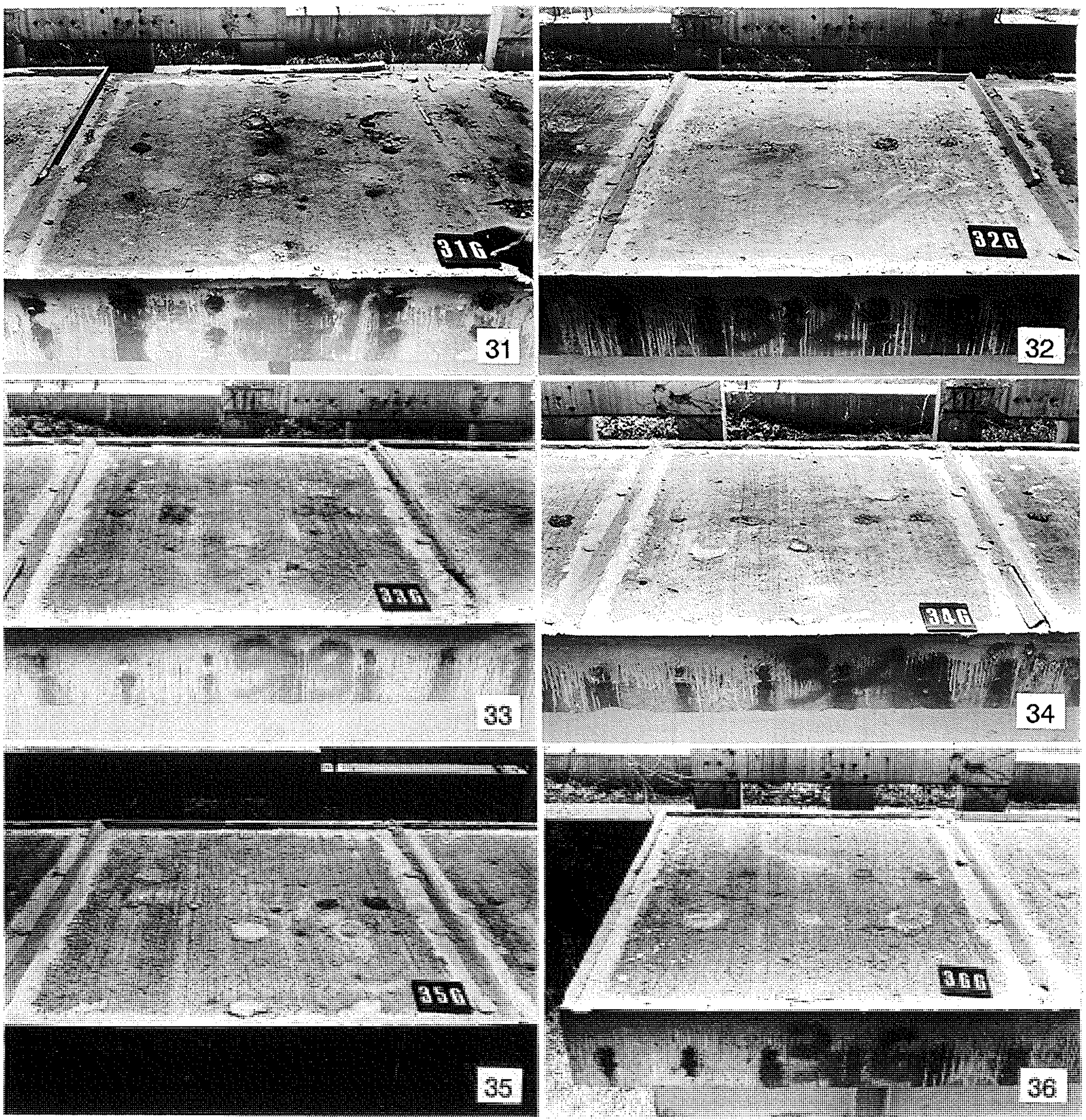


Figure 4 Continued. Appearance of galvanized field exposure specimens after 17 years of exposure. Simulated bridge deck slab specimens presented in order of increasing depth of cover (left to right and top to bottom).

Half-Cell Measurements

Half-cell measurements, taken at intervals during the course of the project, are reported in Table 3. From the very beginning (i.e., measurements taken after the first winter's salting) almost all the half-cell values have been consistently above the -0.35 v level that presumably indicates a 90 percent or greater chance of corrosion occurring. The only exception being the 2-in. and greater cover portion of the simulated deck section and even here the values are all above -0.20 and closer to -0.35 v. (In this range the corrosion activity is regarded as uncertain.) A possible implication here is that salt has penetrated to the reinforcement level for all cover depths (i.e., up to 2 in.) of the field specimens. Although this might seem unlikely after only one winter other researchers have reported similar results.

While the differences between the half-cell values of different categories of specimens are not great enough to attach much significance to, the differences, in general, do at least correspond to trends that would be expected and for that reason are listed here.

Half-cell values are, in general, lower for the greater cover depths although there is quite a bit of overlap of the values. To the extent that the magnitude of half-cell values can reflect the extent of corrosion occurring, this would be expected since penetration of salt and water to the reinforcement should take longer to reach greater depths.

Half-cell values are, in general, slightly less for the lower water/cement ratio concrete mixes. This would be expected since the lower water levels should be reflected in lower permeability of the concrete which in turn would allow less water and salt to penetrate to the reinforcement level.

Half-cell values are also slightly lower for the uncoated bars than for the galvanized bars. Implications here are difficult to interpret since half-cell values for the galvanized bars may involve 'mixed' potential values from both zinc and iron oxidation.

Several slabs had half-cell measurements taken for both the top and bottom mats with the mats electrically isolated and then with the mats shorted. Results showed an apparent shifting of the macrocells when the mats were shorted although differences in absolute potential values were not great.

Normally, half-cell data would include equipotential maps and cumulative frequency distributions for all relevant specimens. While this could be done, the lack of any real change in magnitude of the values makes such an action essentially pointless. The half-cell values are recorded in Appendix E, however, for those interested in examining them further.

Equipotential maps and cumulative frequency distributions for several representative specimens are shown in Figure 5. Agreement between

TABLE 3
HALF-CELL MEASUREMENTS FOR GALVANIZED FIELD EXPOSURE SPECIMENS

Experimental Details			Half-Cell Potentials Over Uncoated Bars, Negative Volts (Average)								Half-Cell Potentials Over Galvanized Bars, Negative Volt (Average)							
Concrete Cover	Cement sacks/cu yd	Water, gal/sack	6/71	8/73	8/74	9/75	8/76	8/81	9/84	9/85	6/71	8/73	8/74	9/75	8/76	8/81	9/84	9/85
1/2**	6	6	0.58	0.58	0.56	0.53	0.54	0.55	–	–	0.78	0.56	0.60	0.55	0.52	0.54	–	–
	6*	5-1/4	0.56	0.65	0.62	0.52	0.49	0.50	–	–	0.78	0.61	0.62	0.51	0.44	0.49	–	–
	6	5-1/4	0.56	0.56	0.59	0.55	0.44	0.49	–	–	0.74	0.52	0.63	0.55	0.43	0.50	–	–
	7-1/2	4-1/2	0.55	0.56	0.60	0.57	0.56	0.56	–	–	0.66	0.54	0.67	0.54	0.56	0.54	–	–
1-1/4	6	6	0.48	0.50	0.48	0.60	0.52	0.60	0.66	0.62	0.60	0.54	0.52	0.52	0.48	0.58	0.68	0.62
	6*	5-1/4	0.50	0.48	0.51	0.55	0.46	0.57	0.64	0.58	0.71	0.56	0.58	0.54	0.46	0.56	0.67	0.60
	6	5-1/4	0.50	0.50	0.43	0.52	0.51	0.60	0.64	0.60	0.56	0.54	0.59	0.55	0.47	0.57	0.63	0.57
	7-1/2	4-1/2	0.38	0.46	0.41	0.46	0.52	0.72	0.55	0.52	0.45	0.50	0.45	0.36	0.44	0.54	0.49	0.38
2	6	6	0.49	0.42	0.47	0.52	0.49	0.56	0.62	0.57	0.55	0.47	0.49	0.51	0.46	0.56	0.62	0.57
	6*	5-1/4	0.53	0.44	0.48	0.51	0.58	0.62	0.64	0.61	0.61	0.57	0.60	0.65	0.59	0.62	0.64	0.61
	6	5-1/4	0.41	0.42	0.45	0.44	0.51	0.56	0.64	0.57	0.47	0.48	0.51	0.48	0.54	0.57	0.65	0.60
Simulated Deck Section																		
1/2	6*	5+	–	0.62	0.57	0.49	0.66	–	–	–	–	–	–	–	–	–	–	–
1/2	6	5+	0.60	0.59	0.53	0.42	0.63	–	–	–	0.68	0.51	0.57	0.40	0.60	–	–	–
1	6	5+	0.51	0.54	0.52	0.39	0.54	–	0.50	0.59	0.59	0.52	0.50	0.48	0.48	–	0.46	0.62
1-1/2	6	5+	0.44	0.49	0.45	0.45	0.54	0.45	0.63	0.51	0.41	0.47	0.42	0.41	0.45	0.41	0.61	0.48
2	6	5+	0.31	0.41	0.36	0.36	0.40	0.40	0.58	0.47	0.27	0.40	0.34	0.35	0.38	0.37	0.54	0.43
2-1/2	6	5+	0.28	0.37	0.29	0.31	0.36	0.34	0.47	0.41	0.28	0.34	0.29	0.32	0.36	0.35	0.47	0.42
3	6	5+	0.27	0.34	0.29	0.31	0.36	0.37	0.52	0.48	0.30	0.38	0.30	0.31	0.37	0.41	0.59	0.52
3-1/2	6	5+	0.29	0.41	0.30	0.37	0.42	0.42	0.59	0.50	0.35	0.44	0.49	0.46	0.51	0.48	0.64	0.55

* Bar splices present

** 1/2-in. specimens were discontinued after 1981

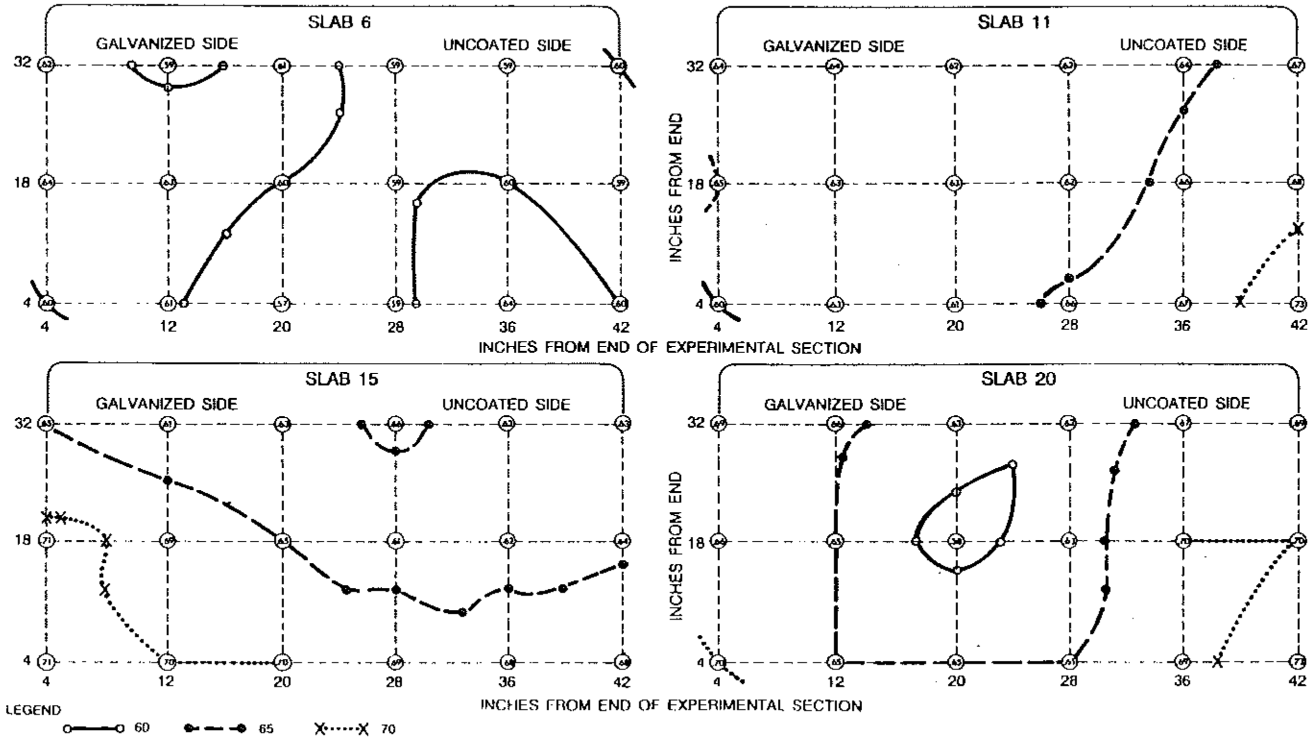
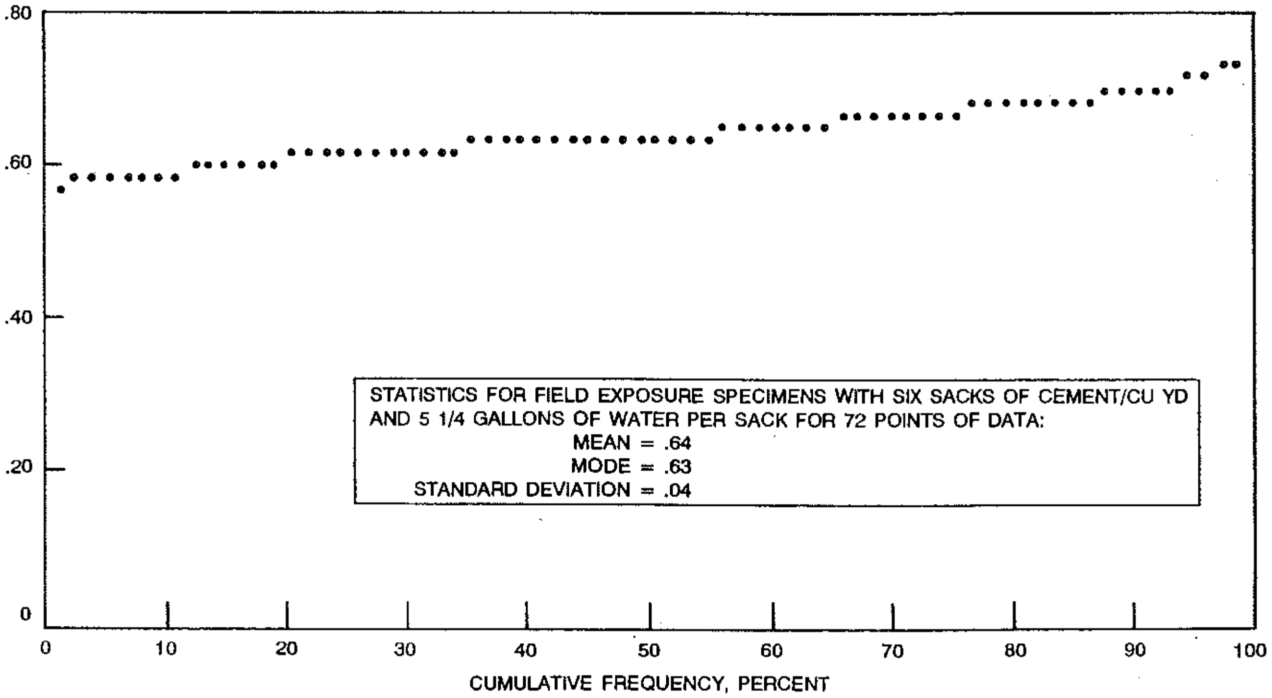


Figure 5. Equipotential plots of representative galvanized field exposure specimens.



STATISTICS FOR FIELD EXPOSURE SPECIMENS WITH SIX SACKS OF CEMENT/CU YD AND 5 1/4 GALLONS OF WATER PER SACK FOR 72 POINTS OF DATA:

MEAN = .64

MODE = .63

STANDARD DEVIATION = .04

Figure 5 Continued. half-cell cumulative frequency distribution of representative field exposure specimens.

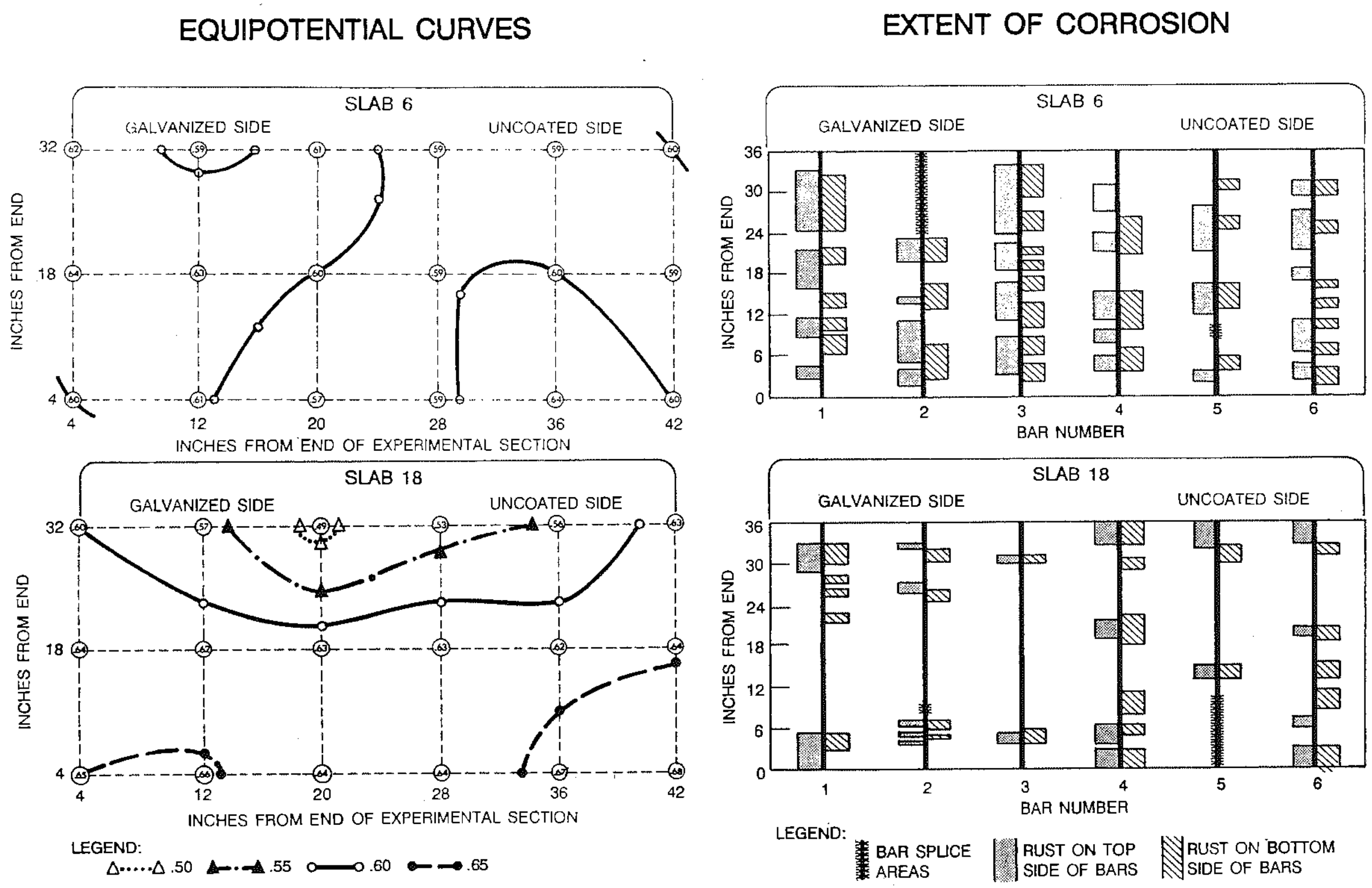


Figure 6. Equipotential plot of half-cell potentials vs. actual location of corrosion for representative galvanized field exposure specimens.

the equipotential maps and actual locations of corrosion are not, in general, as good as would be desirable given the widespread use of half-cell values for defining active corrosion areas in concrete structures. Higher half-cell values are, presumably, more likely to be associated with areas of actual corrosion. The equipotential maps of Figure 5 are referenced against the actual physical locations of corrosion, as determined by visual inspection of the bars following demolition of the slabs, in Figure 6. A number of factors possibly come into play. Actual corrosion is a cumulative phenomenon that reflects fluctuating high corrosion areas that may not be incorporated into a one time or once a year measurement. Half-cell magnitudes are also affected by variables other than corrosion rate (i.e., moisture and oxygen content) that may reflect slight differences in the concrete composition and physical condition. The size of these slabs may also represent too small of an area to reflect changes in values (bridge deck values are not showing vast changes over distances on the order of the slab sizes--see Appendix A, pages 25 and 27); the electrical potential shifts generated by any corrosion activity may be affecting the readings of the entire slab. The exposed ends of the reinforcement, which are periodically drenched with saltwater when rainfall overflows the dikes, or heavy corrosion activity on either the uncoated or galvanized side may be dominating the half-cell values.

Data regarding the actual corrosion of the reinforcement is discussed in more detail in the section Reinforcement Corrosion.

Macrocell Corrosion Current

Macrocell corrosion currents between the top and bottom mats are recorded in Table 4. Given the high variation between the values, averaging did not seem appropriate so the values for each individual slab are given in the table. Where multiple entries occur in the columns the same slab will occupy the same position in the adjacent columns. While in some cases the current for the whole slab roughly equals the sum of its uncoated and galvanized bars, this was not always true. Apparently there were sufficient differences between the uncoated and galvanized sides of these slabs to effect a complete shifting of the macrocell distribution once the two sides were reconnected.

As seen in the table, there is roughly as large a variation between individual slab specimens for any given category as exists for any other category (with only one obvious exception). In some cases, the uncoated bars are corroding more and sometimes the galvanized bars are. Sometimes the top mat is corroding more than the bottom mat and sometimes the reverse is true. The numbers here do not provide a clue as to which concrete mix or which reinforcement may actually have an advantage in the real world.

Some measurements were also made of the corrosion currents between the uncoated and galvanized portions of the top mats. These values would probably be more indicative of the corrosion performance of the slabs

TABLE 4
MACROCELL CORROSION CURRENTS FOR GALVANIZED FIELD EXPOSURE SPECIMENS

Experimental Details			Current (After Fifteen Winters)		Current (After Seventeen Winters)		
Concrete Cover**	Cement, sacks/cu yd	Water, gal/sack	Uncoated Bars, microAmps	Galvanized Bars, microAmps	Uncoated Bars, microAmps	Galvanized Bars, microAmps	Both Bars, microAmps
1-1/4	6	6	--	--	-822, 917, 2600	1867, 298,572	2910,1055,-1642
	6*	5-1/4	--	--	186, -294	657,230	363, 30
	6	5-1/4	--	--	-12140, -231	3500, 8	3058, -195
	7-1/2	4-1/2	--	--	683	407	1016
2	6	6	--	--	856	577	1183
	6*	5-1/4	--	--	-42, 617	996,745	804, 1267
	6	5-1/4	--	--	286, 194, 829	1086,3013,451	1259,2090, 1042
Simulated Deck Section							
1/2	6	5+	--	--	--	--	--
1	6	5+	--	--	-1403	1836	400
1-1/2	6	5+	767	453	854	575	1738
2	6	5+	316	302	170	80	226
2-1/2	6	5+	119	164	370	27	362
3	6	5+	198	329	178	955	1090
3-1/2	6	5+	743	276	-500	1790	970

* Bar splices present
** 1/2-in. specimens no longer existed

when the longitudinal reinforcement was still intact; this represents roughly the first 15 years of weathering for these specimens. The values obtained are widely scattered and while generally showing the galvanized side to be sacrificial to the uncoated side, this was not always true. Since only a few measurements of this type were taken, the values are not reported here. More importance would have been attached to these measurements if a better understanding of what was probably occurring within the slabs had existed at the time the measurements were taken.

Problems with the lack of a viable trend in the data probably relate to a number of factors. As previously mentioned, the macrocell corrosion current measurement is more likely to be a reflection of how the specimens would have performed had the top and bottom mats been electrically connected (as typically occurs in actual decks). Corrosion current is also an instantaneous measurement and may not adequately reflect the actual cumulative corrosion which eventually results in damage. Corrosion of reinforcement is typically regarded as having changes in magnitude by a factor of 2 within days and may change by a factor of 10 or more over the course of a year. The most corrosive areas of a given structure may also shift from time to time.

Additional factors which have probably affected these results relate specifically to our specimens. Several problems were created by the manner in which the slabs were constructed. Leaving the ends of the reinforcement exposed outside the concrete allowed an alternate source of corrosion separate from what would normally occur in a real deck. Runoff from the slab surfaces was allowed to run down the sides of the specimens further complicating the corrosion reactions taking place. Salt could, to some extent, penetrate the slabs from the sides and bottom in addition to normal surface penetration. This configuration of the slabs, with no electrical connection between the top and bottom mats, and combined surface and side salting with protruding reinforcement has created a situation where the most prominent macrocell probably occurs between the sides and the center of the slab for both the top and bottom mats. While these factors do not prevent an analysis from being made of the performance of the various slabs, they do modify the corrosion patterns from what would be more expected in more realistic decks and make the usefulness of top/bottom mat current measurements questionable since the primary corrosion probably occurs within a given mat. The greatest differences in the environment surrounding the reinforcement and, therefore, the greatest potential for corrosion, probably occurs between the edges and center portions of a mat rather than between the top and bottom mats.

The macrocell corrosion values for the simulated bridge deck section show some pretty clear evidence for the benefits of greater depth of cover. Corrosion currents, at least for the separate uncoated and galvanized sides, show a clear reduction in macrocell current as the cover depth increases. Beyond roughly 3 in. of cover another problem comes into play and apparently overrides the effect of increased cover. As can be seen in Figure 2, the increased depth of cover for the top mat is obtained by decreasing the distance between the top and bottom mats. At some point this decreased distance allows for greater corrosion as the effective ion and electron path between the two mats is decreased. As existed for the individual slabs problems with the surface runoff appear to be present here also with salt penetrating from the side and possibly bottom of the simulated deck making the bottom mat the anode for the uncoated portion of 3-1/2 in. cover depth. The galvanized top mat appears to be overriding this factor and is, as would be expected, the 'sacrificial' anode for the galvanized portion of the 3-1/2 in. cover depth.

Electrical Resistance

While resistance measurements in concrete are typically done using alternating currents (ac), a direct current (dc) method seemed more appropriate for this project. While concrete typically has a high resistivity, the top and bottom mats create, effectively, a parallel circuit path with a much reduced total resistance. Typical resistance values between the top and bottom mats for the concrete used in Michigan bridge decks range from roughly 10 to 20 ohms (dc) when first poured with gradually decreasing values as salt and moisture penetrate the deck. Also, when a macrocell is acting between the top and bottom mats; it is the dc rather than the ac potential that affects the current flow.

Electrical (dc) resistance measurements were made between the top and bottom reinforcement mats of all slabs. It was hoped this would provide a measure of the condition of the concrete between the mats since the resistance would be a function of the porosity of the concrete, degree of impregnation of chloride ions, amount of moisture present, presence of vertical cracks between the mats, etc. While the value does not tell which of these parameters has been modified, it does provide a quantitative value representative of all these parameters combined. The resistance values would, to some extent, also be indicative of the ease of ion travel (i.e., necessary for macrocell corrosion) between the top (anode) and bottom (cathode) mats. Resistance measurements for the various simulated bridge deck slabs are recorded in Table 5.

Several interesting trends are readily apparent in the data. Most obvious is the large decrease in magnitude of the values from 15 to 17 years of exposure. While the decrease might represent just the deterioration of the concrete, it is more likely that the large differences seen here also reflect a higher moisture content in the concrete at the time of the second set of measurements.

Higher resistances are also apparent for the lower water/cement ratios although there is some overlap of the data. This would be expected since the reduced porosity of these concretes should restrict chloride ion and water penetration.

Higher resistances are also readily apparent in the simulated deck section for the greater depths of cover even though the distance of

TABLE 5
AVERAGE dc ELECTRICAL RESISTANCE MEASUREMENTS BETWEEN THE TOP AND BOTTOM REINFORCEMENT MATS FOR GALVANIZED FIELD EXPOSURE SPECIMENS

Experimental Details			Resistance (After 15 Winters)	Resistance (After 17 Winters)		
Concrete Cover**	Cement, sack/cu yd	Water, gal/sack	Both Uncoated and Galvanized Bars, ohms	Uncoated Bars, ohms	Galvanized Bars, ohms	Both Bars, ohms
1-1/4	6	6	9.3	5.5	6.8	5.4
	6*	5-1/4	15.5	14.1	12.3	7.4
	6	5-1/4	10.5	13.2	20.2	7.5
	7-1/2	4-1/2	22.0	23.1	33.2	17.0
2	6	6	18.6	--	--	--
	6*	5-1/4	16.8	6.6	6.8	3.9
	6	5-1/4	18.8	7.8	8.1	4.4
Simulated Deck Section						
1/2	6	5+	--	15.6	10.8	7.8
1	6	5+	13.8	8.1	9.0	4.8
1-1/2	6	5+	22.5	10.5	14.3	6.0
2	6	5+	29.0	13.8	17.1	7.8
2-1/2	6	5+	46.3	17.9	21.9	10.5
3	6	5+	19.2	10.3	10.0	5.4
3-1/2	6	5+	13.7	7.6	7.8	4.9

* Bar splices present
**1/2-in. specimens no longer existed

separation is correspondingly reduced (see Fig. 2). For roughly 3 in. of cover and greater, the increased corrosion (see Macrocell Corrosion Current section) resulting from the decreased top/bottom mat separation has resulted in actual cracking of the concrete between the mats and reduced resistance values.

The resistances between the galvanized top mats and uncoated bottom mats are consistently higher than those between the uncoated top and bottom mats with only several exceptions (i.e., 1/2-in. cover, 3-in. and greater cover, and the use of bar splices) that probably relate to cracking of the concrete. The higher values of resistance for the galvanized reinforcement is of interest since the consistency of these differences suggests that more than a chance factor is involved. What is probably happening here is that the corrosion of the zinc is creating an oxide with relatively high electrical resistance. This in turn implies that the zinc is behaving in a normal anodic (i.e., sacrificial) manner since this is when zinc corrosion creates an electrically insulating oxide ($Zn(OH)_2$). (When acting in an undesirable cathodic (non-sacrificial) manner, zinc corrosion produces a semiconducting oxide (ZnO) which can be noble to both iron and zinc and promote further corrosion of both the intact zinc coating as well as the iron substrate.) The galvanized reinforcement as tested here appears to be performing as typically desired and may have an added benefit of effectively healing itself as the buildup of insulating zinc oxide electrically isolates the most corrosive areas from further corrosion.

TABLE 6
AVERAGE CHLORIDE ION CONCENTRATIONS FOR THE GALVANIZED FIELD EXPOSURE SPECIMENS AT SEVERAL DEPTHS

	Experimental Details			Chloride Concentration, lb/cu yd									
	Concrete Cover	Cement, sacks/cu yd	Water, gal/sack	From the Uncoated Side at Depth (in.)			From the Galvanized Side at Depth (in.)			Average of Doth Sides at Depth (in.)			
				1.25	2.00	2.70	1.25	2.00	2.75	1.25	2.00	2.75	6.00
After Six Winters	1/2	6	6	17.5	13.7	13.6	17.0	11.3	10.0	17.3	12.5	11.8	---
		6	5-/14	12.5	11.2	9.6	13.9	11.6	8.1	13.2	11.4	8.8	---
		7-1/2	4-1/2	10.4	9.1	7.8	15.6	9.2	6.9	13.0	9.2	7.4	---
	1-1/4	6	6	16.2	12.7	10.7	13.9	10.7	8.9	15.1	11.7	9.8	---
		6	5-1/4	10.8	12.0	9.6	12.7	10.1	7.4	11.7	11.0	8.5	---
		7-1/2	4-1/2	10.1	4.0	2.6	5.8	2.1	0.7	8.0	3.0	1.6	---
	2	6	6	15.5	16.0	10.0	21.3	13.2	8.4	18.4	14.6	9.2	---
		6	5-1/4	10.8	10.4	5.9	9.3	7.4	6.6	10.0	8.9	6.3	---
	Weighted Average of all Cover Depths	6	6	16.5	13.6	11.5	16.2	11.3	9.2	16.4	12.5	10.4	---
		6	5-1/4	11.7	11.0	8.2	11.7	9.5	7.3	11.7	10.3	7.8	---
		7-1/2	4-1/2	10.3	7.4	6.1	12.4	10.4	4.8	11.4	8.9	5.5	---
After Eleven Winters	1/2	6	6	13.0	12.1	11.3	13.6	11.6	11.0	13.3	11.9	11.1	11.1
		6	5-1/4	11.0	9.1	8.3	11.7	9.5	9.1	11.3	9.3	8.7	6.1
		7-1/2	4-1/2	11.8	9.1	9.4	10.2	9.2	7.0	11.0	9.2	8.2	4.0
	1-1/4	6	6	13.6	11.4	10.0	12.6	11.7	10.6	13.1	11.6	10.3	7.7
		6	5-1/4	12.2	10.1	9.4	12.2	9.9	8.2	12.2	10.0	8.8	5.4
		7-1/2	4-1/2	10.5	8.8	4.9	7.1	4.0	1.3	8.8	6.4	3.1	6.7
	2	6	6	15.3	13.7	11.4	16.5	15.4	13.9	15.9	14.6	12.7	11.4
		6	5-1/4	10.8	10.0	8.8	11.8	10.4	9.8	11.3	10.2	9.3	6.6
	Weighted Average of all Cover Depths	6	6	13.7	12.0	10.7	13.4	12.3	11.3	13.5	12.2	11.0	9.5
		6	5-1/4	11.3	9.8	8.9	11.9	9.9	9.1	11.6	9.9	9.0	6.0
		7-1/2	4-1/2	11.4	9.0	7.8	9.1	7.5	5.1	10.3	8.3	6.4	4.9

Chloride Concentrations

Chloride concentrations (total, acid soluble, chlorides) were measured from cores taken in the uncoated and galvanized sides of the simulated bridge deck slabs after six and eleven winters of exposure. The average chloride concentrations are presented in Table 6.

The cores were taken from central locations in the slabs and will not reflect the salt that has entered the side of the slabs from periodic overflow/runoff.

Average chloride ion penetration is clearly related to the depth from the surface and the water/cement ratio of the concrete. There is considerable overlap among the data for individual measurements, however, as can be seen from reviewing the data in Appendix F.

While the variations of concrete mix used in this project have an obvious difference on the average effective porosity of the concrete with respect to chloride ion penetration, none of these mixes would provide adequate protection by themselves. After only six winters sufficient salt (i.e., equal to, or greater than 1-1.4 lb/cu yd) penetrated to the top mat that corrosion could be expected to occur for all specimens. After 11 winters, sufficient salt has penetrated to the bottom mat to expect corrosion here also, although the higher concentrations in the top mat would make it more likely to be the corroding anode in decks with electrical contact between the mats.

Reinforcement Corrosion

Average corrosion of the reinforcement is represented in Table 7. Only 'red' rusting of iron from the uncoated reinforcement or as part of zinc-iron alloy layer of the galvanizing is included in the table; the white oxide from intact galvanizing proved too hard to properly visually discriminate from the concrete residue left on the bars removed from the demolished slabs. Corrosion is measured as affected surface area. In general, this number would be expected to correlate fairly well with total metal loss.

In general, corrosion is more extensive on the galvanized side of the slabs providing further evidence that the zinc coating performed in a sacrificial manner. Corrosion is less evident for the lower water/cement ratios for all of the slab combinations except the 1-1/4-in. depth of cover over uncoated reinforcement.

Less corrosion of the top mats also occurred for greater depths of cover.

Miscellaneous

Several problems with the design and maintenance of the simulated bridge deck slabs have caused problems with interpretation of the experi-

TABLE 7
APPROXIMATE AREAS OF SURFACE CORROSION ON THE REINFORCEMENT USED IN THE GLAVANIZED FIELD EXPOSURE SPECIMENS AFTER SEVENTEEN WINTERS

Experimental Details			Top Mat		Bottom Mat**	
Concrete Cover*	Cement, sacks/cu yd	Water, gal/sack	Uncoated Bars, percent	Galvanized Bars, percent	Under Uncoated Bars, percent	Under Galvanized Bars, percent
1-1/4	6	6	35	65	30	35
	6	5-1/4	50	55	20	25
2	6	6	25	45	40	45
	6	5-1/4	20	30	40	45

* 1/2-in. specimens no longer existed and bars from the simulated deck section were too badly damaged, during deck demolition, to include in this evaluation

** All reinforcement in the bottom mat is uncoated

mental results. While some of these problems have been previously referred to in the text, they are worth mentioning here also so that: 1) others will not repeat the same mistakes; and, 2) some allowance may be made in the interpretation of the results.

The slabs (Fig. 2) used both uncoated and galvanized reinforcement in the top mat. While the original intention was to better discriminate the performance differences between uncoated and galvanized reinforcement by placing them both in the same batch of concrete under identical conditions, this is not quite what happens when the different metals are effectively electrically connected. When two different metals are in electrical contact, galvanic (i.e., dissimilar metal) corrosion can occur. For the combination of metals represented here (zinc and steel), the zinc will, in general, be sacrificial and corrode preferentially at its own expense while protecting the steel. While this particular element of corrosion knowledge was not readily known to highway engineers when this project was first implemented, this is probably not as true today; and, hence, this type of mistake would probably not be repeated. This factor does, however, influence the manner in which the results should be interpreted.

The typical theoretical model for bridge deck corrosion that is now prevalent, depicts the majority of corrosion as resulting from a macrocell established between the top (anode) and bottom (cathode) mats with the differences in salt concentration between the mats being a major driving force. This model requires an electrical link between the top and bottom mats which the experimental specimens used on this project did not have. (While it is true that some current can pass between the top and bottom mats without a 'direct' electrical link, this current will, in general, be small compared to that which can occur with a direct electrical link due to the higher electrical resistance in the deck and the battery like nature of the corrosion process.) This will modify the degree of corrosion that occurs on the experimental slabs as well as the distribution

TABLE 8
KNOWN VARIABLES MOST LIKELY TO INFLUENCE THE PERFORMANCE OF THE EPOXY COATED FIELD SPECIMENS

Experimental Details

Slab No.	Pour No.	Concrete Cover, in.	Cement, sacks/ cu yd	Water, gal/sack	Coating* Type	Surface** Treatment	Air Content, percent	Slump, in.	Compressive Strength, psi
1	2	1-1/4	6	5-1/2	Red Epoxy	NWMB	?	?	?
2	2	1-1/4	6	5-1/2	Green Epoxy	WMB	?	?	?
3	1	1-1/4	6	5-1/2	Gray Epoxy	NWMB	?	?	?
4	3	1-1/4	6	5-1/2	1/2 Gal	–	?	?	?
5	1	1-1/4	6	5-1/2	Red Epoxy	WMB	?	?	?
6	3	1-1/4	6	5-1/2	Green Epoxy	NWMB	?	?	?
7	2	1-1/4	6	5-1/2	Gray Epoxy	CB	?	?	?
8	3	1-1/4	6	5-1/2	Red Epoxy	CB	?	?	?
9	3	1-1/4	6	5-1/2	Gray Epoxy	CB	?	?	?
10	1	1-1/4	6	5-1/2	Red Epoxy	CB	?	?	?
11	2	1-1/4	6	5-1/2	Red Epoxy	CB	?	?	?
12	1	1-1/4	6	5-1/2	Green Epoxy UCC	NWMB	?	?	?
13	3	1-1/4	6	5-1/2	Gray Epoxy	WMB	?	?	?
14	1	1-1/4	6	5-1/2	Galvanized	–	?	?	?
15	2	1-1/4	6	5-1/2	Uncoated	–	?	?	?
16	3	1-1/4	6	5-1/2	Red Epoxy	WMB	?	?	?
17	2	1-1/4	6	5-1/2	1/2 Gal	–	?	?	?
18	3	1-1/4	6	5-1/2	Red Epoxy	NWMB	?	?	?
19	1	1-1/4	6	5-1/2	Gray Epoxy	CB	?	?	?
20	2	1-1/4	6	5-1/2	Green Epoxy	CB	?	?	?
21	1	1-1/4	6	5-1/2	Green Epoxy	NWMB	?	?	?
22	3	1-1/4	6	5-1/2	Green Epoxy UCC	WMB	?	?	?
23	1	1-1/4	6	5-1/2	1/2 Gal	–	?	?	?
24	2	1-1/4	6	5-1/2	Green Epoxy UCC	WMB	?	?	?
25	1	1-1/4	6	5-1/2	Green Epoxy	WMB	?	?	?
26	2	1-1/4	6	5-1/2	Gray Epoxy	WMB	?	?	?
27	3	1-1/4	6	5-1/2	Gray Epoxy	NWMB	?	?	?
28	1	1-1/4	6	5-1/2	Red Epoxy	NWMB	?	?	?
29	2	1-1/4	6	5-1/2	Gray Epoxy	NWMB	?	?	?
30	3	1-1/4	6	5-1/2	Galvanized	–	?	?	?
31	2	1-1/4	6	5-1/2	Green Epoxy	NWMB	?	?	?
32	3	1-1/4	6	5-1/2	Green Epoxy	CB	?	?	?
33	1	1-1/4	6	5-1/2	Uncoated	–	?	?	?
34	2	1-1/4	6	5-1/2	Red Epoxy	WMB	?	?	?
35	3	1-1/4	6	5-1/2	Green Epoxy	WMB	?	?	?
36	1	1-1/4	6	5-1/2	Gray Epoxy	WMB	?	?	?
37	2	1-1/4	6	5-1/2	Galvanized	–	?	?	?
38	1	1-1/4	6	5-1/2	Green Epoxy	CB	?	?	?

* Coatings used are as follows:
Gray Epoxy - Cooks 720-A-009
Green Epoxy - 3M Epoxy 202
Red Epoxy - Dupont Flintflex 531-608

** Abbreviations for surface preparations are as follows:
CB - Commercial Blast
NWMB - Near White Metal Blast
WMB - White Metal Blast
UCC - Uncoated Chairs
1/2 Gal - Top mat reinforcement galvanized/bottom mat uncoated

of the corrosion. Future slabs should incorporate an electrical contact between the top and bottom mats, preferably external to the deck to allow monitoring of the corrosion current.

Overflow of the water collecting on the slabs would periodically allow salt to penetrate the sides and, possibly, the bottom of the slabs. This would modify the distribution of salt from what would normally be expected in a real deck (i.e., higher concentration of salt as one approaches the surface of the deck) for the edges of the top mat and especially for the bottom mat. Macrocell corrosion currents typically generated from differences in salt concentration would be modified by the modified distribution. This is especially relevant for the bottom mat which would not normally experience the degree of difference of salt concentrations undoubtedly occurring for these specimens. The 'macrocell' corrosion established within the bottom mat is probably as bad or worse than any occurring within the top mat. This could be corrected on future specimens by either allowing a runoff provision that bypasses the sides of the specimens or alternately coating the sides of the specimens with an appropriate barrier material. Some attempts were made to seal the sides of the specimens but these coatings failed early on in the project. Newer materials would, hopefully, perform much better.

The ends of the reinforcement extended out of the concrete and were exposed to atmospheric corrosion conditions that have, undoubtedly, had an influence on both the performance of the slabs and some of the techniques (half-cell potentials) used to monitor the corrosion of the slabs. Future problems along this line could be prevented by ensuring that the reinforcement is either incorporated into the concrete or sealed with an appropriate coating. Some attempts were made to see that the ends of the reinforcement on these specimens were periodically coated; but the materials available for this purpose, at the time, did not perform well enough to ensure that corrosion of the reinforcement ends did not occur.

Epoxy Coated (73 F-131)

Initial Details

Table 8 summarizes the known variables that most probably influence the performance of the field specimens. The three separate concrete pours that were used to make the specimens have been listed since the pour batch was found to have a significant effect on performance as determined by at least one of our measuring techniques. Since all of the pours had been intended to be essentially identical, some measures of the concrete that might otherwise have been recorded are unfortunately lacking and have been represented in the table by question marks.

Table 9 summarizes the performance of the coating during bending of the reinforcement. Although the data are scattered, two factors appear to be quite evident:

TABLE 9
INITIAL AND SUBSEQUENT BEND TEST DATA FOR EPOXY COATED REINFORCEMENT

Epoxy Coating	Initial Bend Tests* (Fabricator A)										
	Surface Preparation	No. of Cracks	Thin < 5 mils			Within Spec. 5 -9 mils			Thick > 9 mils		
			No. 4 Bar	No. 5 Bar	No. 6 Bar	No. 4 Bar	No. 5 Bar	No. 6 Bar	No. 4 Bar	No. 5 Bar	No. 6 Bar
Green	White Metal Blast	0 - 1	1			2	5	2	2		3
		2 - 10									
		> 10									
	Near-White Metal Blast	0 - 1			1	2	4	4	2		
		2 - 10				1	1				
		> 10									
	Commercial Blast	0 - 1	1			2			2		
		2 - 10									
		10			2		5	3			
Red	White Metal Blast	0 - 1				2		4	3	5	1
		2 - 10									
		> 10									
	Near-White Metal Blast	0 - 1			1	5	4	4		1	
		2 - 10									
		> 10									
	Commercial Blast	0 - 1	1			3	2		1		
		2 - 10									
		> 10		1			2	4			1
Gray	White Metal Blast	0 - 1		1		3	1	3	2	1	
		2 - 10					2	1			1
		> 10									
	Near-White Metal Blast	0 - 1		3		2	2	3	1		1
		2 - 10						1			
		> 10	1			1					
	Commercial Blast	0 - 1				1			2		
		2 - 10								2	
		> 10				1	1	4	1	2	1

Epoxy Coating	Initial Bend Tests (Fabricator B)										
	Surface Preparation	No. of Cracks	Thin < 5 mils			Within Spec. 5 - 9 mils			Thick > 9 mils		
			No. 4 Bar	No. 5 Bar	No. 6 Bar	No. 4 Bar	No. 5 Bar	No. 6 Bar	No. 4 Bar	No. 5 Bar	No. 6 Bar
Green	White Metal Blast	0 - 1	1			2		2			
		2 - 10		1			1	2			
		> 10		1		1	1	1			
	Near-White Metal Blast	0 - 1		1							
		2 - 10									
		> 10	1	3	1	3		4			
	Commercial Blast	0 - 1									
		2 - 10									
		> 10	2			1	4	3	1	1	2
Red	White Metal Blast	0 - 1	5	5	4			1			
		2 - 10									
		> 10									
	Near-White Metal Blast	0 - 1									
		2 - 10			2						
		> 10	5	5	3						
	Commercial Blast	0 - 1									
		2 - 10									
		> 10	5	5	4			1			
Gray	White Metal Blast	0 - 1									
		2 - 10									
		> 10			1			4			
	Near-White Metal Blast	0 - 1									
		2 - 10									
		> 10									
	Commercial Blast	0 - 1									
		2 - 10									
		> 10									

*Tabulated values indicate number of specimens in each category

TABLE 9 (con't.)
INITIAL AND SUBSEQUENT BEND TEST DATA FOR EPOXY COATED REINFORCEMENT

Epoxy Coating	Bend Tests After 90 Days Outdoors Exposure (Fabricator A)										
	Surface Preparation	No. of Cracks	Thin < 5 mils			Within Spec. 5 -9 mils			Thick > 9 mils		
			No. 4 Bar	No. 5 Bar	No. 6 Bar	No. 4 Bar	No. 5 Bar	No. 6 Bar	No. 4 Bar	No. 5 Bar	No. 6 Bar
Green	White Metal Blast	0 - 1				5	2	2			2
		2 - 10					2			1	1
		> 10									
	Near-White Metal Blast	0 - 1		1		1		3			
		2 - 10				1	1			1	
		> 10			1	1	1	1	2	1	
	Commercial Blast	0 - 1				3					
		2 - 10							2		
		> 10					3	3		1	2
Red	White Metal Blast	0 - 1				5		3		2	
		2 - 10					2			1	
		> 10						1			1
	Near-White Metal Blast	0 - 1	2			3	5	2			
		2 - 10			1			2			
		> 10									
	Commercial Blast	0 - 1				3					
		2 - 10		1		1	1				
		> 10		1	2	1	2	3			
Gray	White Metal Blast	0 - 1				2	2		2		
		2 - 10									
		> 10				1	3	5			
	Near-White Metal Blast	0 - 1		2		3		4			
		2 - 10		1			1		1		
		> 10					1	1			
	Commercial Blast	0 - 1	1			1	3	3			
		2 - 10				2	2	2			
		> 10							1		

Epoxy Coating	Bend Tests After 1 Year Storage in Laboratory (Fabricator A)										
	Surface Preparation	No. of Cracks	Thin < 5 mils			Within Spec. 5 - 9 mils			Thick > 9 mils		
			No. 4 Bar	No. 5 Bar	No. 6 Ber	No. 4 Bar	No. 5 Bar	No. 6 Bar	No. 4 Bar	No. 5 Bar	No. 6 Bar
Green	White Metal Blast	0 - 1	1			2		2			
		2 - 10		1			1	2			
		> 10		2		1		1			
	Near-White Metal Blast	0 - 1		1							
		2 - 10									
		> 10	3		3	1	4	2			
	Commercial Blast	0 - 1									
		2 - 10									
		> 10	3	5	1	2		4			
Red	White Metal Blast	0 - 1	5	5	4			1			
		2 - 10									
		> 10									
	Near-White Metal Blast	0 - 1			1						
		2 - 10			1			1			
		> 10				5	5	2			
	Commercial Blast	0 - 1									
		2 - 10									
		> 10	5	5	4			1			
Gray	White Metal Blast	0 - 1	1	2		3	1	3	1		
		2 - 10					2	1			1
		> 10									
	Near-White Metal Blast	0 - 1	2	3	2	1	2	2			
		2 - 10									
		> 10	1			1		1			
	Commercial Blast	0 - 1	3								
		2 - 10		2	1						
		> 10	2	1			2	3			1

1) There is considerable variation in the curing of the coatings on various bars, even within a given type of coating and bar size.

2) Commercial blast treatment is not adequate preparation for application of epoxy coatings on reinforcement that is going to be bent.

Analysis of variance of the data indicates that:

3) The size of the bar is a highly significant variable (possibly reflecting variations in the heating cycle applied during the coating process as well as different amounts of strain when different bar sizes are bent around a given sized mandrel).

4) The types of coatings are not significantly different in performance when applied by the same fabricator.

5) There was a significant difference in the performance of the same coating when applied by different fabricators.

6) When the source was held constant there was a slight difference between the white metal blast and the near white metal blast.

While there was also an effect due to aging of the coating (at a lower level of significance), it is obvious that general degradation to extreme brittleness did not occur.

While epoxy coating thicknesses were apparently not recorded for the reinforcement used in the field specimens, data are available for the bend specimens which should be representative of these specimens as well. For the approximately 620 bars selected for the bend test evaluation Fabricator A had coated 530 bars with 18 percent below the specified 5 mil minimum and 11 percent above the specified 9 mil maximum. Fabricator B had coated 90 bars with 61 percent below the 5 mil minimum and 4 percent above the 9 mil maximum. Bars from both fabricators were used in the specimens.

Visual Observation

Visual observations were made of the simulated slabs on a periodic basis during the course of the project. Observed performance (as measured by cracking and spall/scale/popout) are recorded in Table 10 after ten winters of exposure. A visual survey was made after four winters of exposure but only negligible deterioration had taken place at that time and hence that information is not included in the table. Appendix D contains a complete record of the recorded visual observations.

Most of the observed differences between slabs occurred for only one of the three concrete pours that was used to construct the slabs. While all three pours were intended to be identical; this, apparently, was not the case. Since almost all (all but two) of the groupings of specimens

TABLE 10
VISUALLY DETECTED DETERIORATION OF EPOXY COATED
FIELD SPECIMENS AFTER TEN YEARS OF EXPOSURE

Experimental Details		Rating of Specimens		Experimental Details		Rating of Specimens	
Coating Type	Pour No.	Open Cracks, lin in.	Popouts, sq in.	Coating Type	Pour No.	Open Cracks, lin in.	Popouts, sq in.
				Red Epoxy			
Uncoated	1	86	0	Commercial Blast	1 & 3	6	4
	2	216	59		2	0	3
				Near White Blast	1 & 3	18	4
1/2 Galvanized	1 & 3	37	2		2	72	13
(Top Mat only)	2	72	14	White Metal Blast	1 & 3	0	0
					2	108	8
Galvanized	1 & 3	3	0	Green Epoxy			
	2	216	7	Commercial Blast	1 & 3	0	0
					2	22	2
Gray Epoxy				Near White Blast	1 & 3	--	6
Commercial Blast	1 & 3	3	1		2	--	4
	2	108	0	White Metal Blast	1 & 3	0	3
Near White Blast	1 & 3	24	0		2	74	0
	2	144	22	White Metal Blast	1 & 3	11	2
White Metal Blast	1 & 3	0	13	Uncoated Chairs	2	0	0
	2	72	0				

contain all three pours in equal numbers, the difference between the pours may not unduly bias the results although it may complicate making correct interpretation of the results. This would be especially true if the differences among identical specimens of the 'bad' pour are greater than the differences observed for the different experimental groups. Since there are no multiple identical specimens made from the 'bad' pour, there is no way to accurately gage the variation that may occur for the 'bad' pour. This aspect limits the ability to draw accurate conclusions from the available data when all three pours are combined. To reduce possible misinterpretations resulting from the 'bad' pour data, the results in Table 10 are separated for the 'bad' pour (No. 2) and the remaining pours (Nos. 1 and 3). (See Appendix D for a separate listing of individual specimens.)

Looking at the data for the 'remaining pours,' the uncoated reinforcement performed the worst with the 1/2 galvanized (i.e., top mat only galvanized) reinforcement being the next worst. The all galvanized (i.e., both top and bottom mats galvanized) reinforcement was competitive with most of the epoxy coated reinforcement. Degree of surface preparation prior to epoxy coating is not as clear cut as might be expected. Typically both the white metal blast and the commerical blast are out performing the near white metal blast, although the differences are not great.

Looking at the 'visual' data for the 'bad' pour suggests some interesting possibilities. For this particular batch of concrete, the green epoxy coated reinforcement appears to have signficiantly outperformed all of the other reinforcement categories. The other epoxies, in general, did not perform much better than the non-epoxy coated reinforcement and the galvanized reinforcement performed similarly to the uncoated reinforcement. One of the suggestions from these data is that galvanized reinforcement may perform well for some concrete mixes and not others. Another suggestion is that some epoxy coatings may perform better than others and an epoxy coating that performs well in one concrete mix may not perform as well in another. This raises some interesting questions about the differences between the good and bad concretes. These differences can only be hypothesized at this time since the concrete from the 'bad' pour is no longer available. While a number of slabs were saved for use in another project (Fig. 7), none of these were made from the 'bad' concrete.

While it is unfortunate that the possible differences in the quality of the separate pours was not noticed prior to the demolition of the specimens, some educated guesses can be made about the possible differences between the batches of concrete. While all of these specimens appear to lack air entrainment, based on the deterioration of the slabs (Fig. 8), pour No. 2 seems to be even more susceptible to freeze/thaw damage and cracking, in general. Possible reasons for the major differences between the pours could relate to problems with the wet cure and, perhaps, a higher water content for pour No. 2. Since these specimens were poured in the field, it is possible that wind may have removed the wet burlap and/or polyethylene film from this particular batch of specimens long before desirable. A higher water content would have also contributed to a greater porosity and possible shrinkage cracking both of which could help to increase the freeze/thaw deterioration.

Photos were taken during the Fall of 1987 at the conclusion of the project (Fig. 8). The slabs are reordered to better highlight any performance variations that have resulted from the variation of the different parameters examined. Photos are ordered according to the coating method for the reinforcement--uncoated, galvanized top mat only, galvanized both top and bottom mats, and epoxy coated both top and bottom mats. The epoxy coated specimens are further ordered according to the degree of surface preparation prior to epoxy coating--commerical blast (CB), near white metal blast (NWMB), and white metal blast (WMB). Specimens 15 and 33 are uncoated. Specimens 4, 17, and 23 have only the top mat galvanized. Specimens 14, 30, and 37 have both top and bottom mats galvanized. Specimens 7 (CB), 9 (CB), 19 (CB), 3 (NWMB), 27 (NWMB), 29 (NWMB), 13 (WMB), 26 (WMB), and 36 (WMB) have a gray epoxy coating. Specimens 20 (CB), 32 (CB), 38 (CB), 6 (NWMB), 21 (NWMB), 31 (NWMB), 2 (WMB), 25 (WMB), and 35 (WMB) have a green epoxy coating. Specimens 12 (WMB), 22 (WMB), and 24 (WMB) have a green epoxy coating and used uncoated chairs separating the top and bottom mats. Specimens 11 (CB), 8 (CB), 10 (CB), 1 (NWMB), 18 (NWMB), 28 (NWMB), 5 (WMB), 16 (WMB), and 34 (WMB) are coated with a red epoxy. Specimens 1, 2, 7, 11, 15, 17, 20, 24 26, 29, 31, 34, and 37 were made from pour No. 2--the specimen numbers for these slabs are underlined in Figure 8 to better highlight them. In general, several different orientations of each individual slab are shown to better illustrate the condition of the slabs.

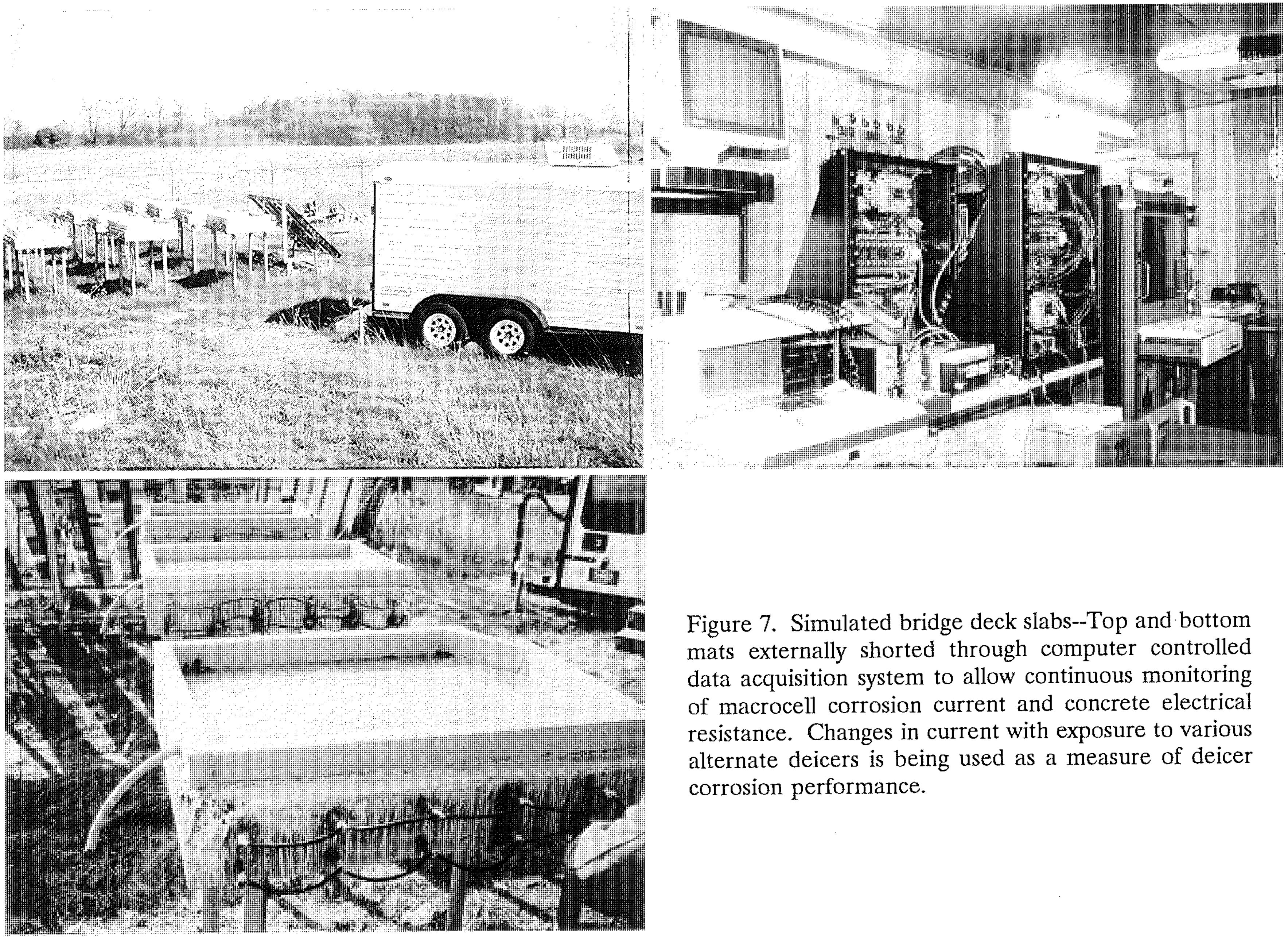


Figure 7. Simulated bridge deck slabs--Top and bottom mats externally shorted through computer controlled data acquisition system to allow continuous monitoring of macrocell corrosion current and concrete electrical resistance. Changes in current with exposure to various alternate deicers is being used as a measure of deicer corrosion performance.

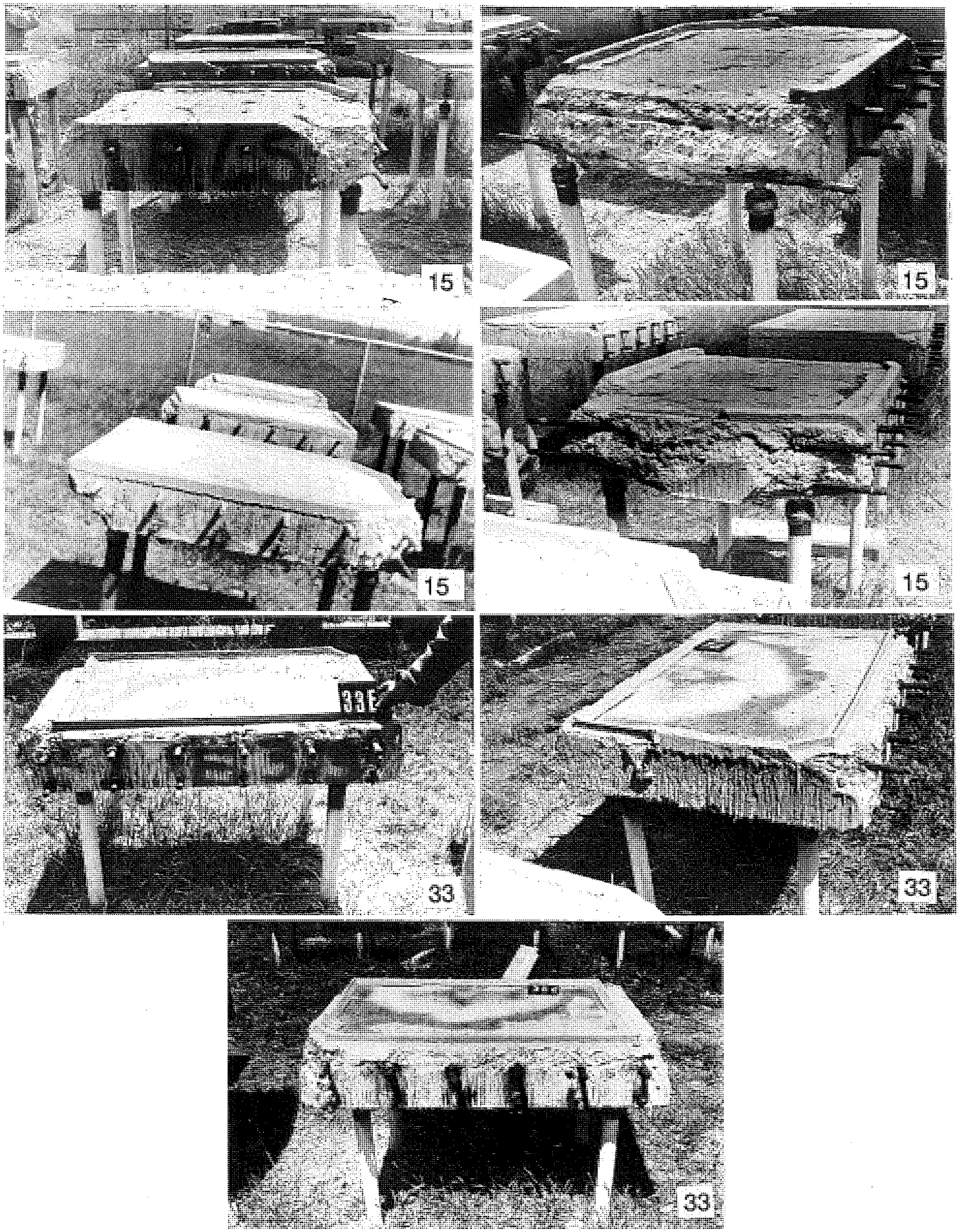


Figure 8. appearance of Epoxy coated field exposure specimens after 13 years of exposure. Uncoated reinforcement.

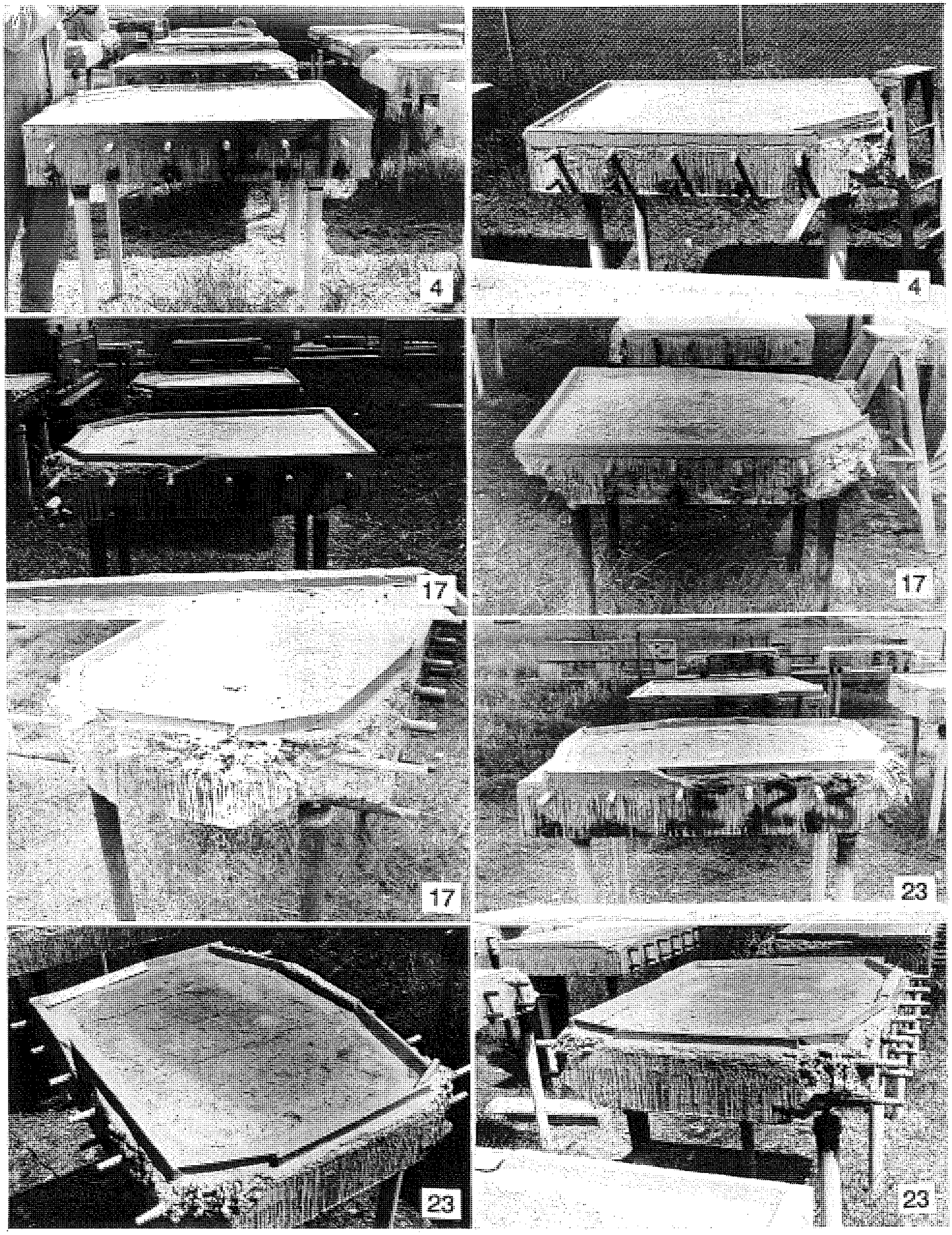


Figure 8 Continued. Appearance of epoxy coated field exposure specimens after 13 years of exposure. Galvanized reinforcement in top mat only.

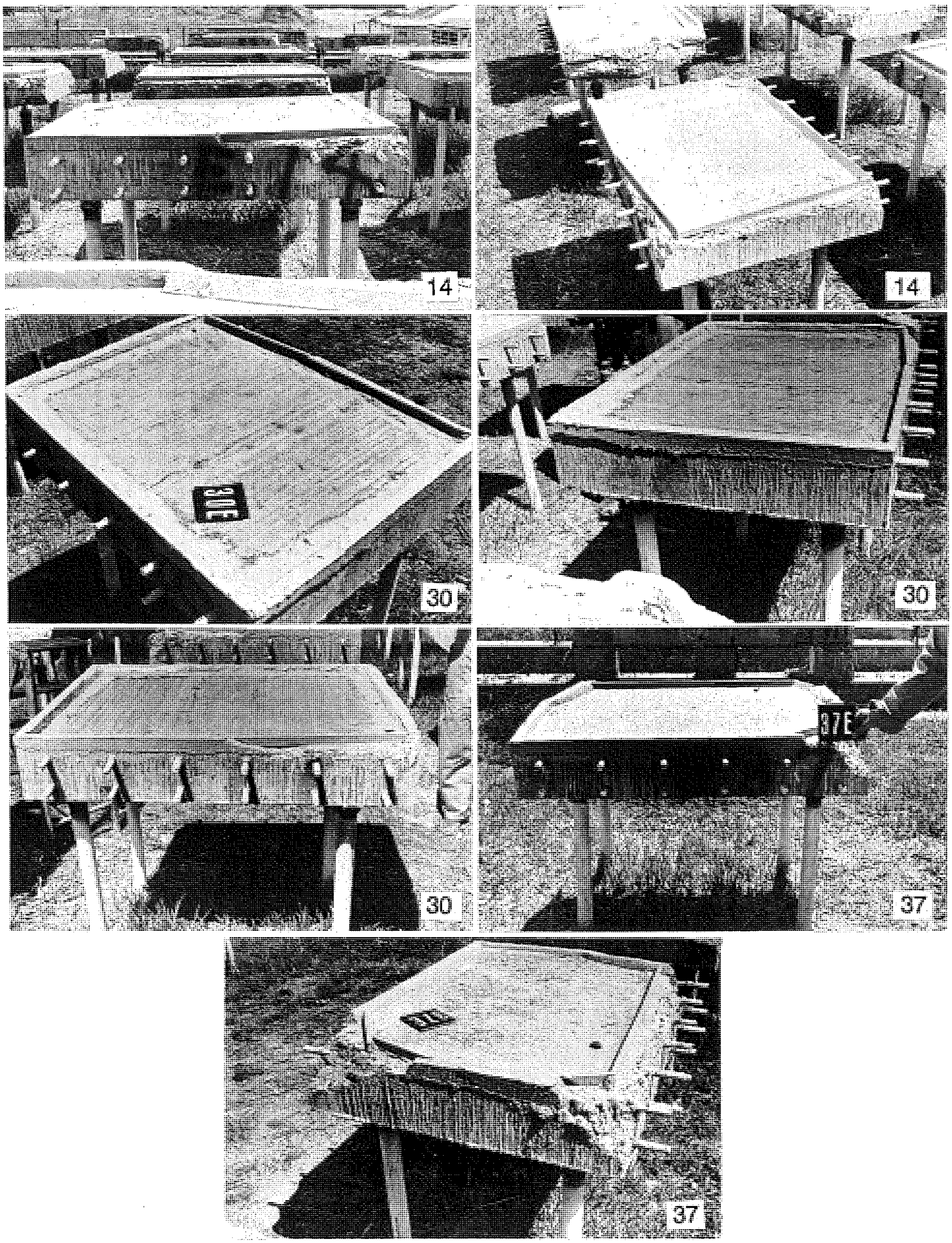


Figure 8 Continued. Appearance of epoxy coated field exposure specimens after 13 years of exposure. Galvanized reinforcement.

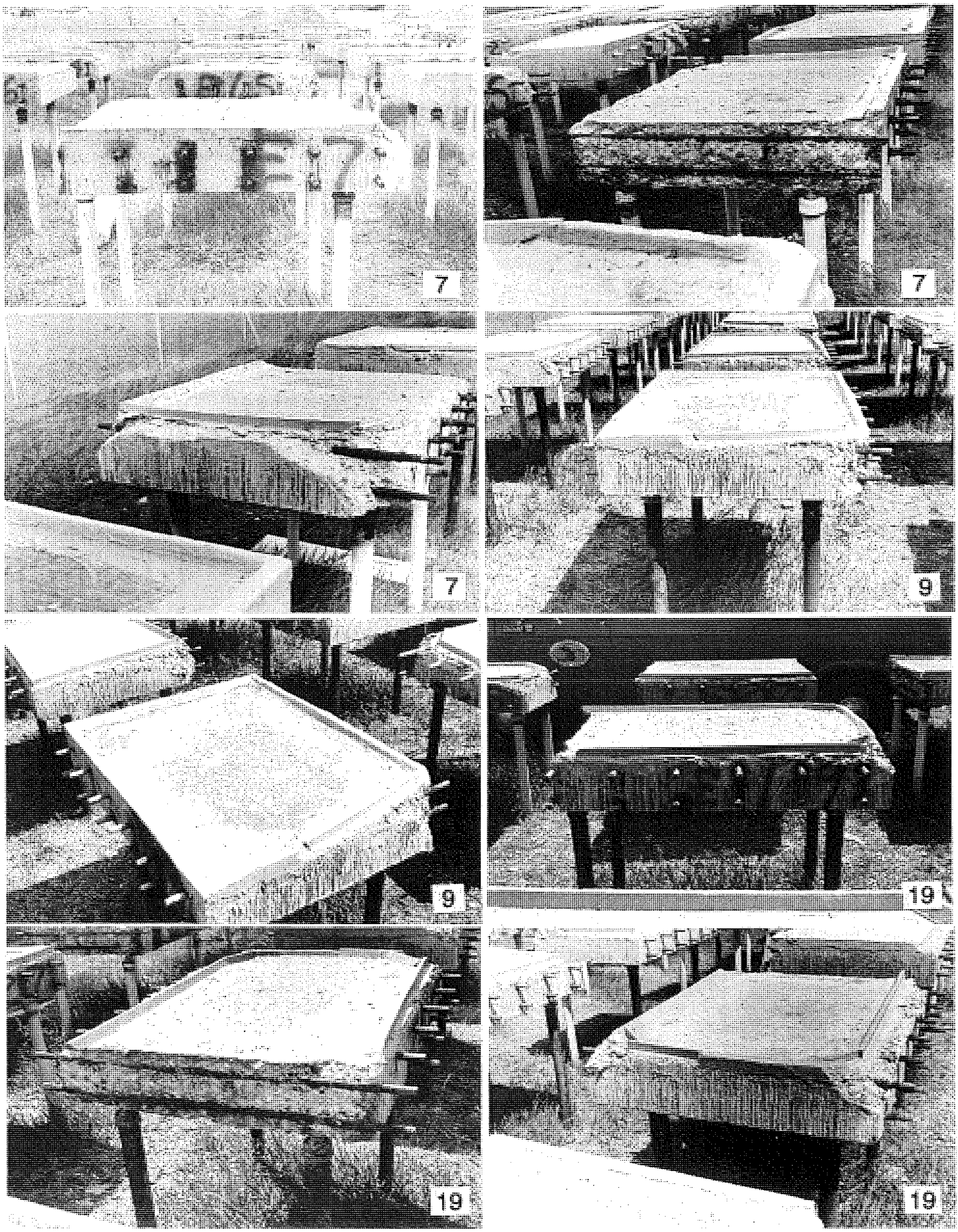


Figure 8 Continued. Appearance of epoxy coated field exposure specimens after 13 years of exposure. Gray epoxy coating over commercial blast.

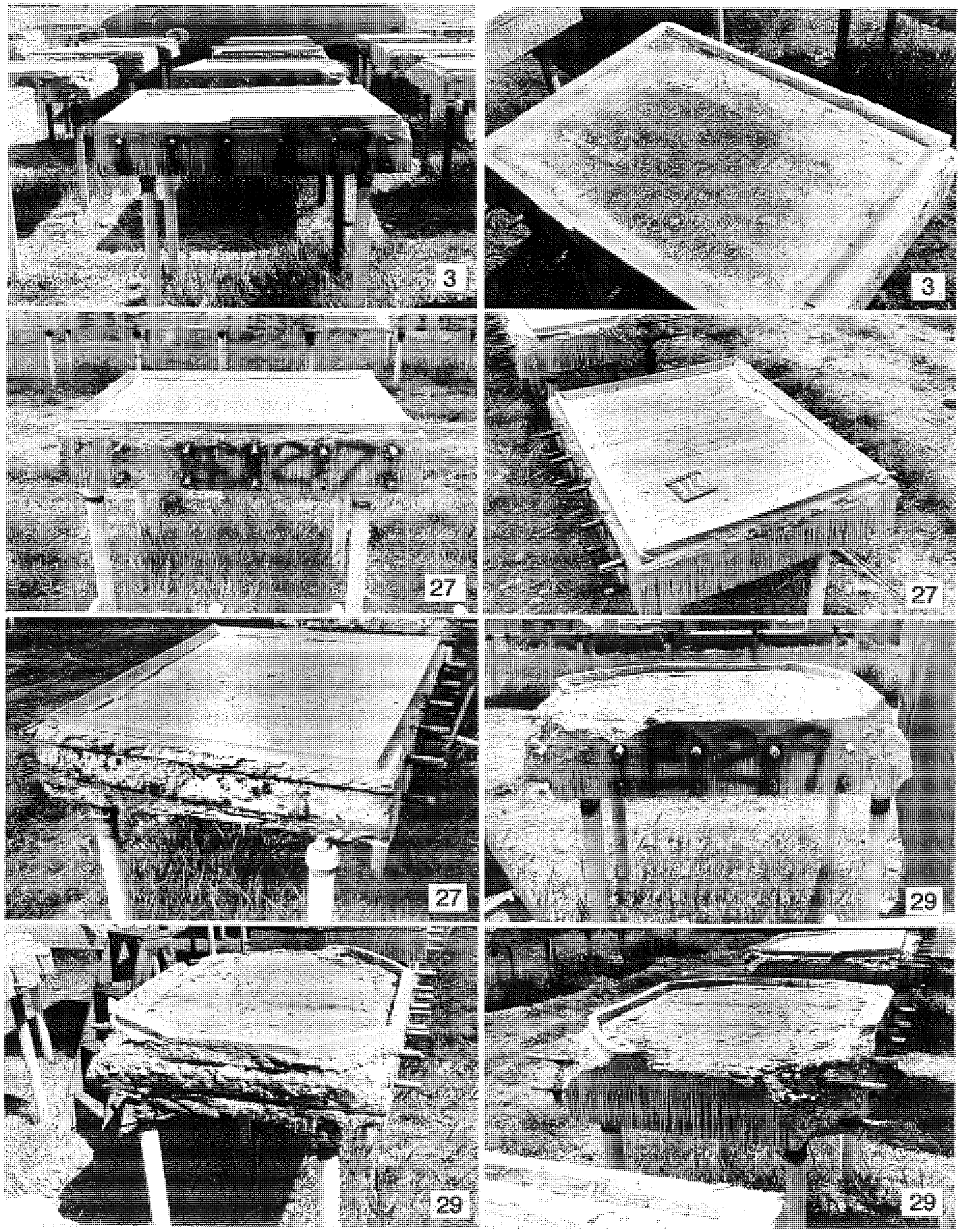


Figure 8 Continued. Appearance of epoxy coated field exposure specimens after 13 years of exposure. Gray epoxy coating over near white metal blast.

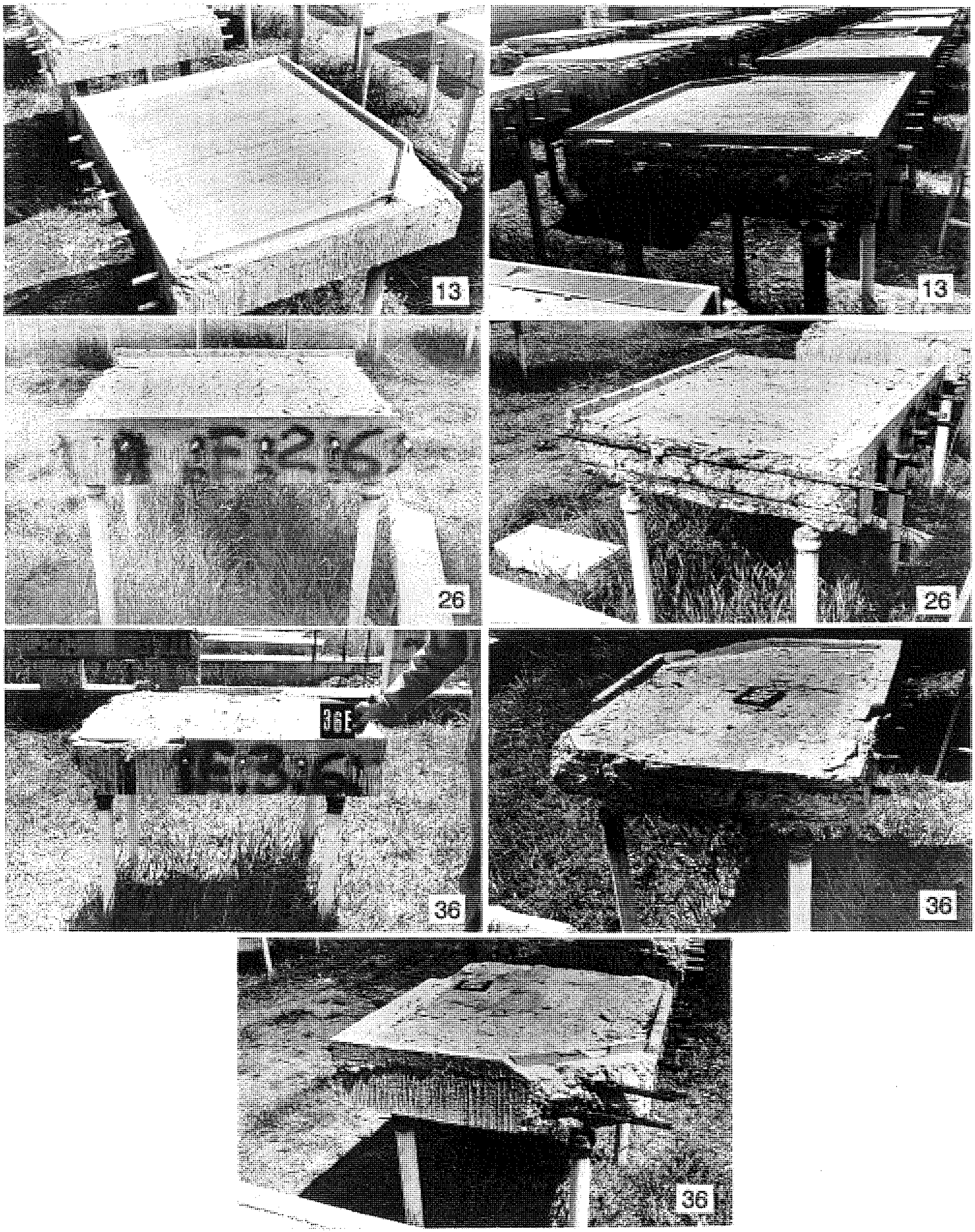


Figure 8 Continued. Appearance of epoxy coated field exposure specimens after 13 years of exposure. Gray epoxy coating over white metal blast.

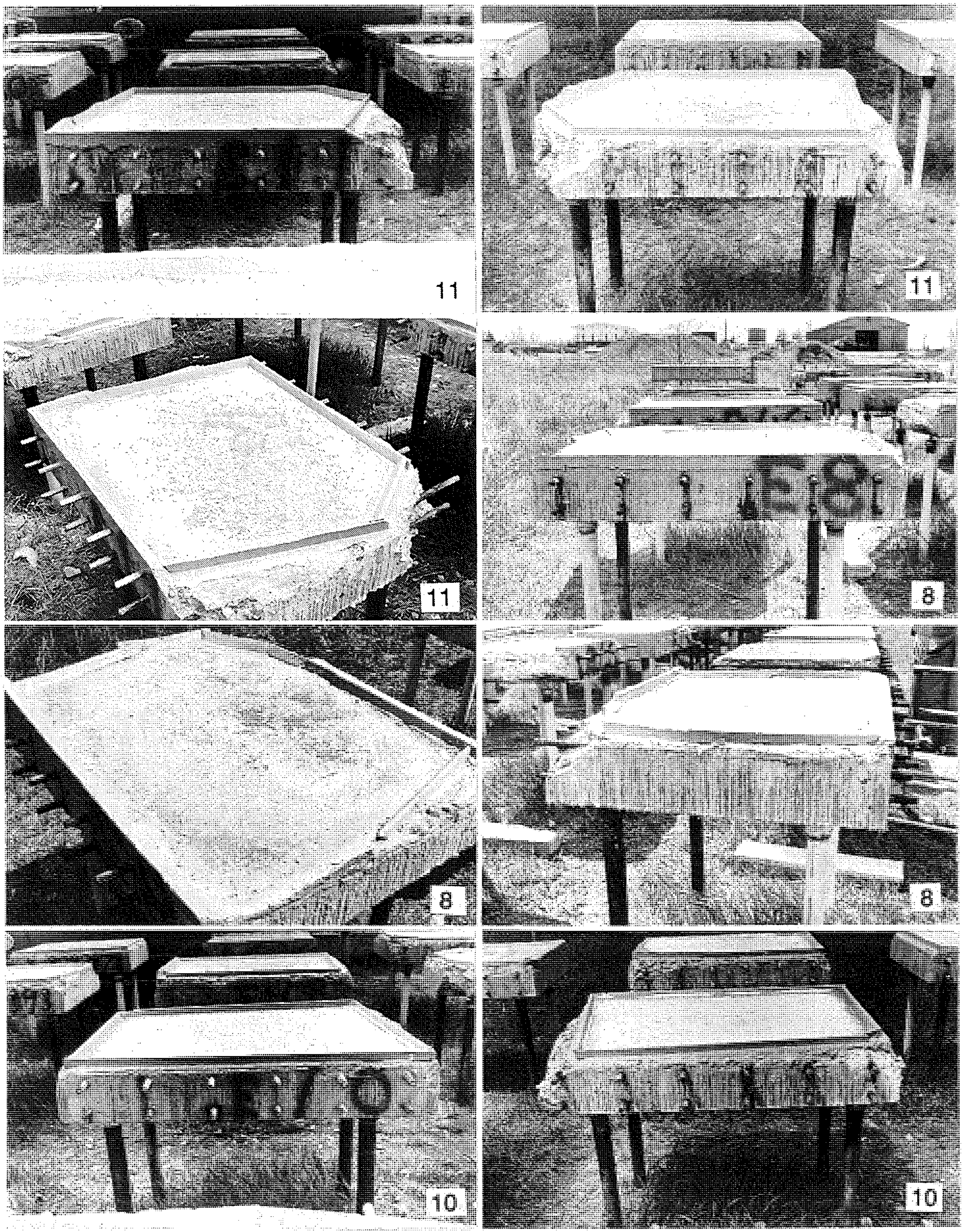


Figure 8 Continued. Appearance of epoxy coated field exposure specimens after 13 years of exposure. Red epoxy coating over commercial blast.

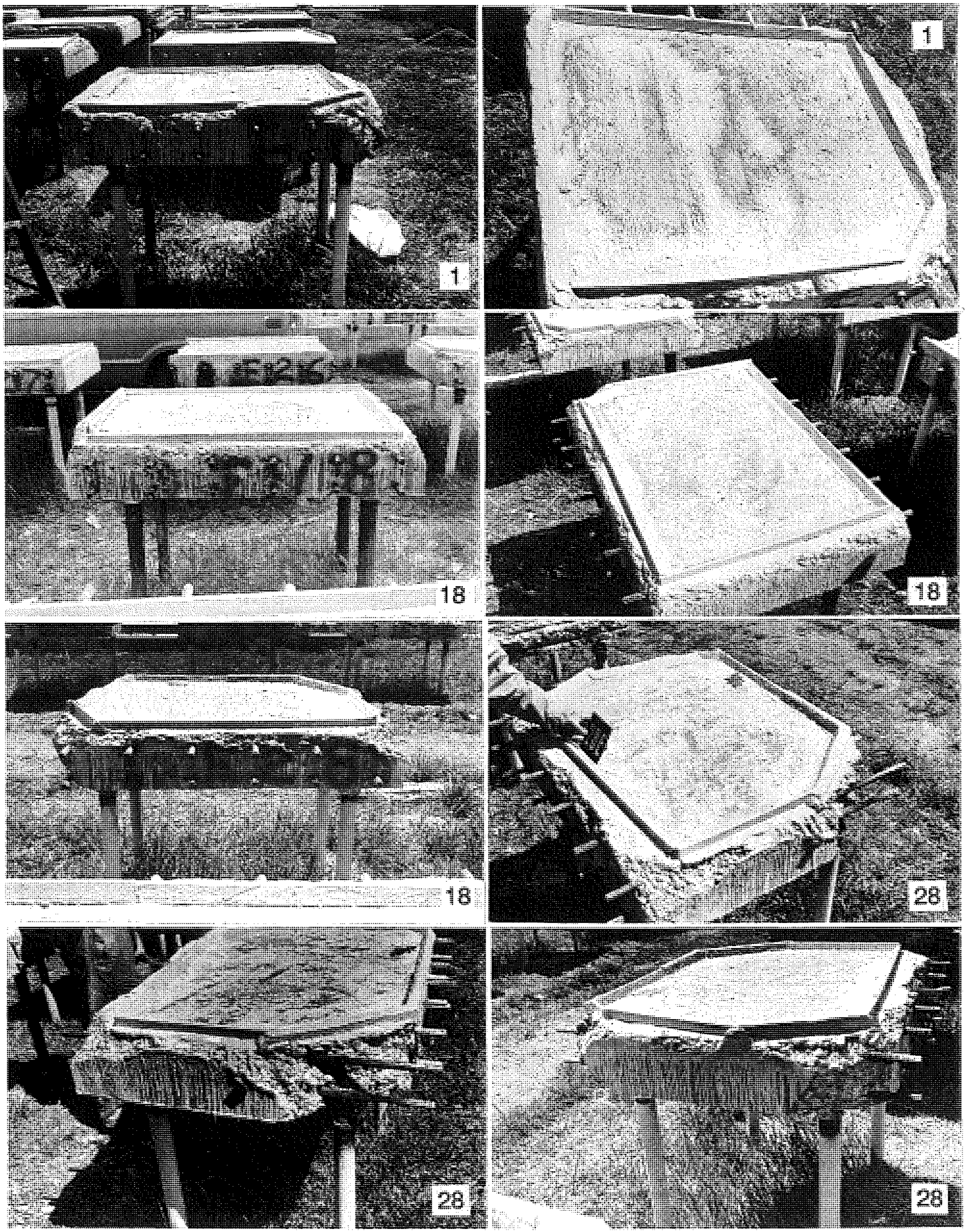


Figure 8 Continued. Appearance of epoxy coated field exposure specimens after 13 years of exposure. Red epoxy coating over near white metal blast.

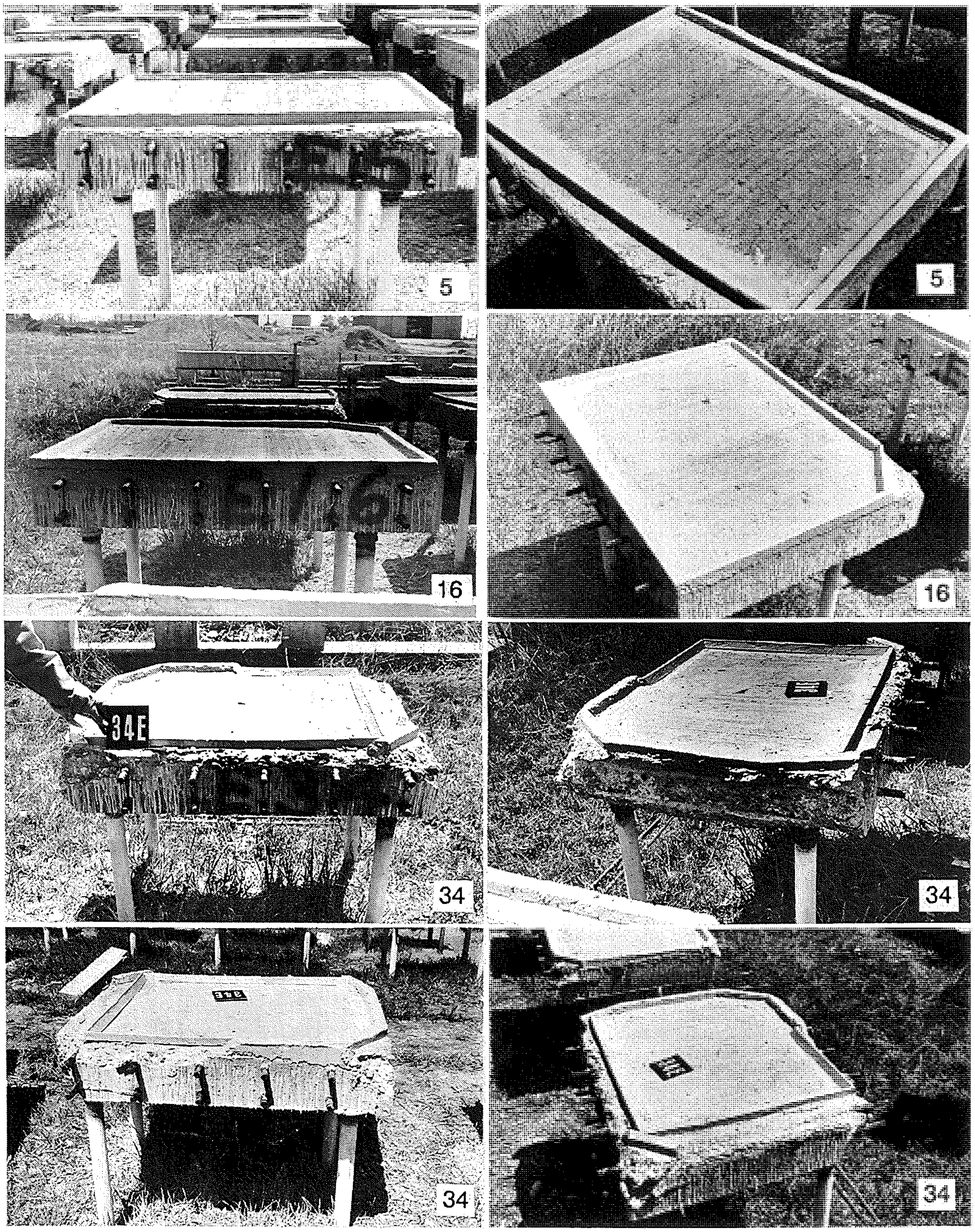


Figure 8 Continued. Appearance of epoxy coated field exposure specimens after 13 years of exposure. Red epoxy coating over white metal blast.

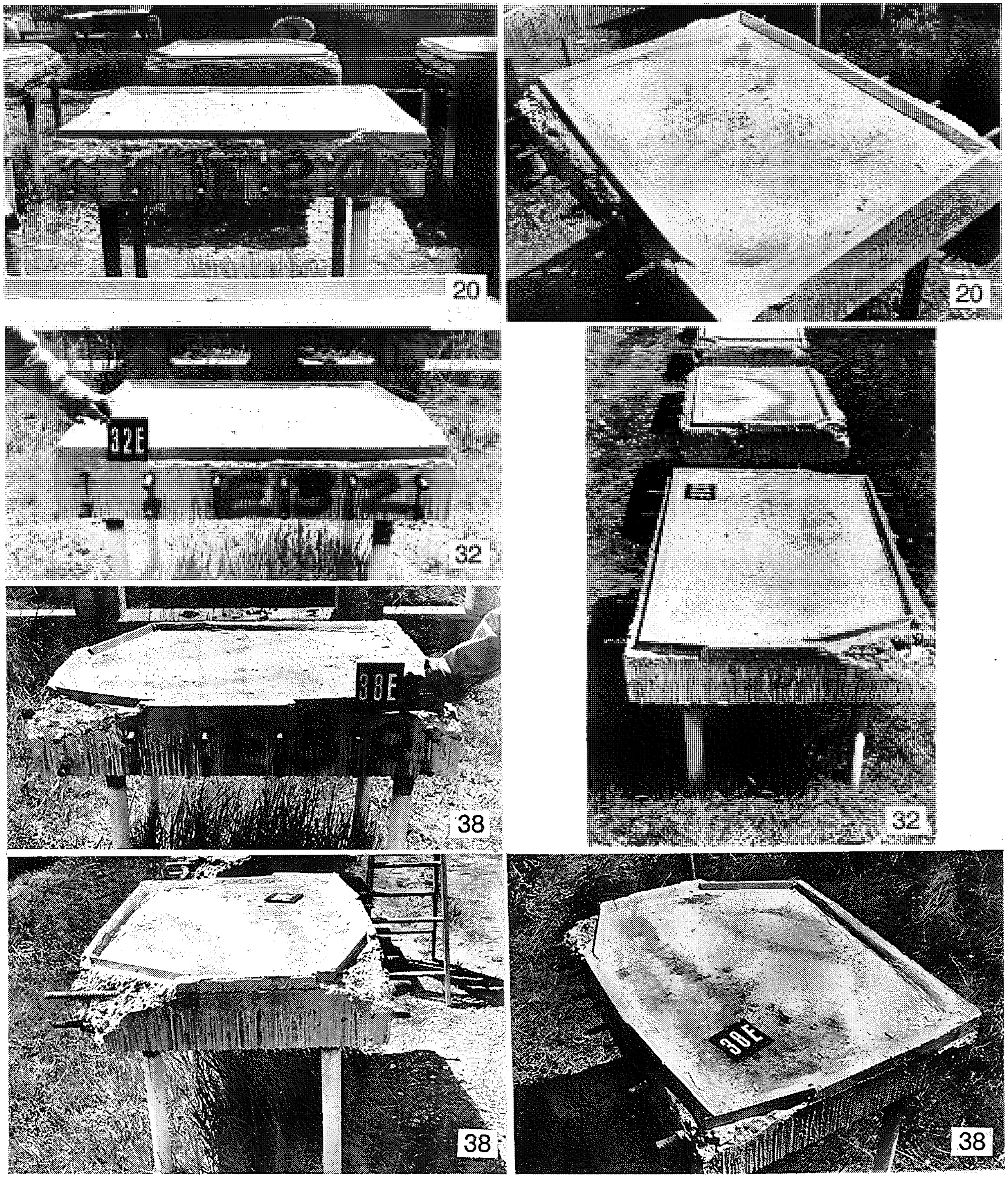


Figure 8 Continued. Appearance of epoxy coated field exposure specimens after 13 years of exposure. Green epoxy coating over commercial blast.

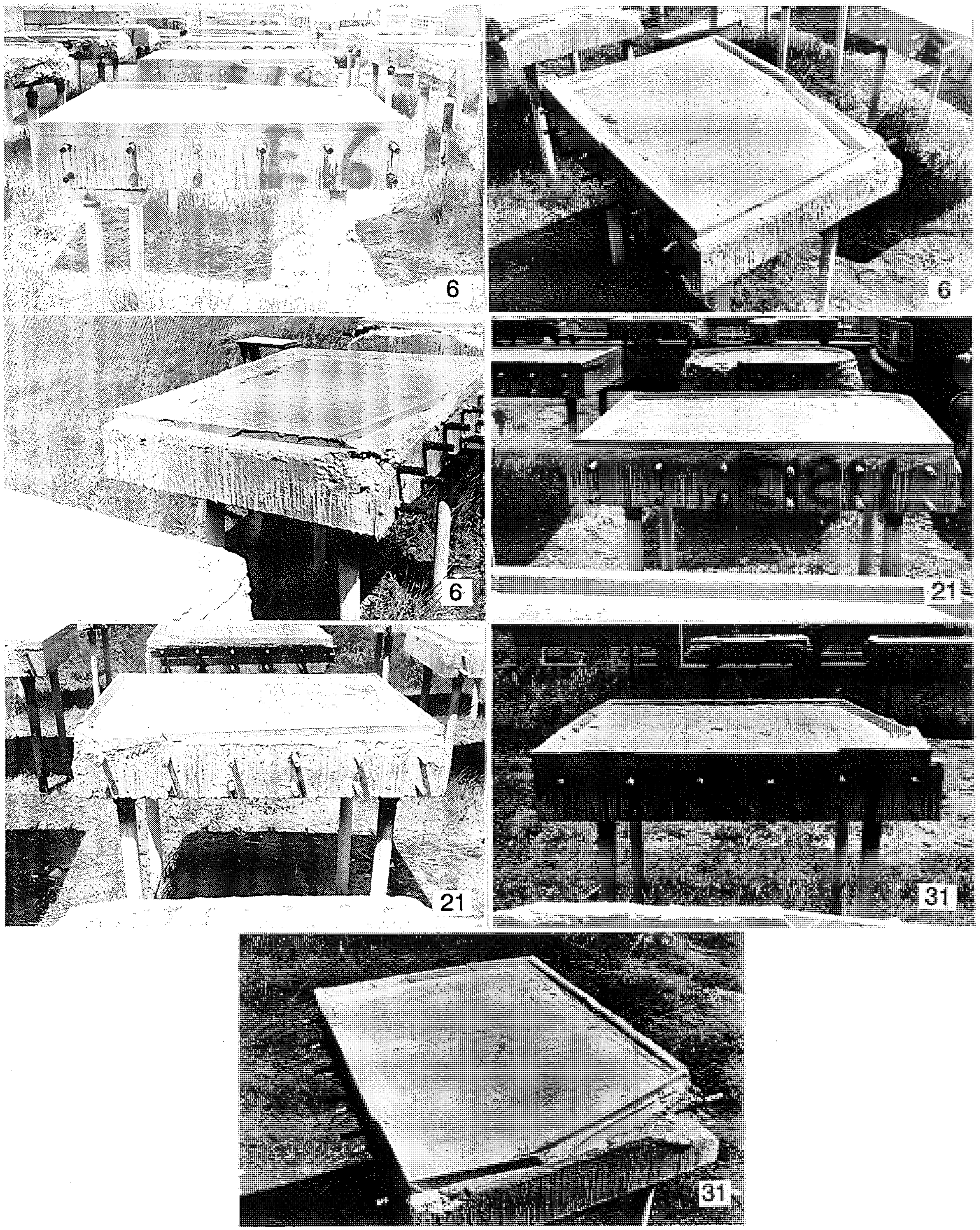


Figure 8 Continued. Appearance of epoxy coated field exposure specimens after 13 years of exposure. Green epoxy coating over near white metal blast.

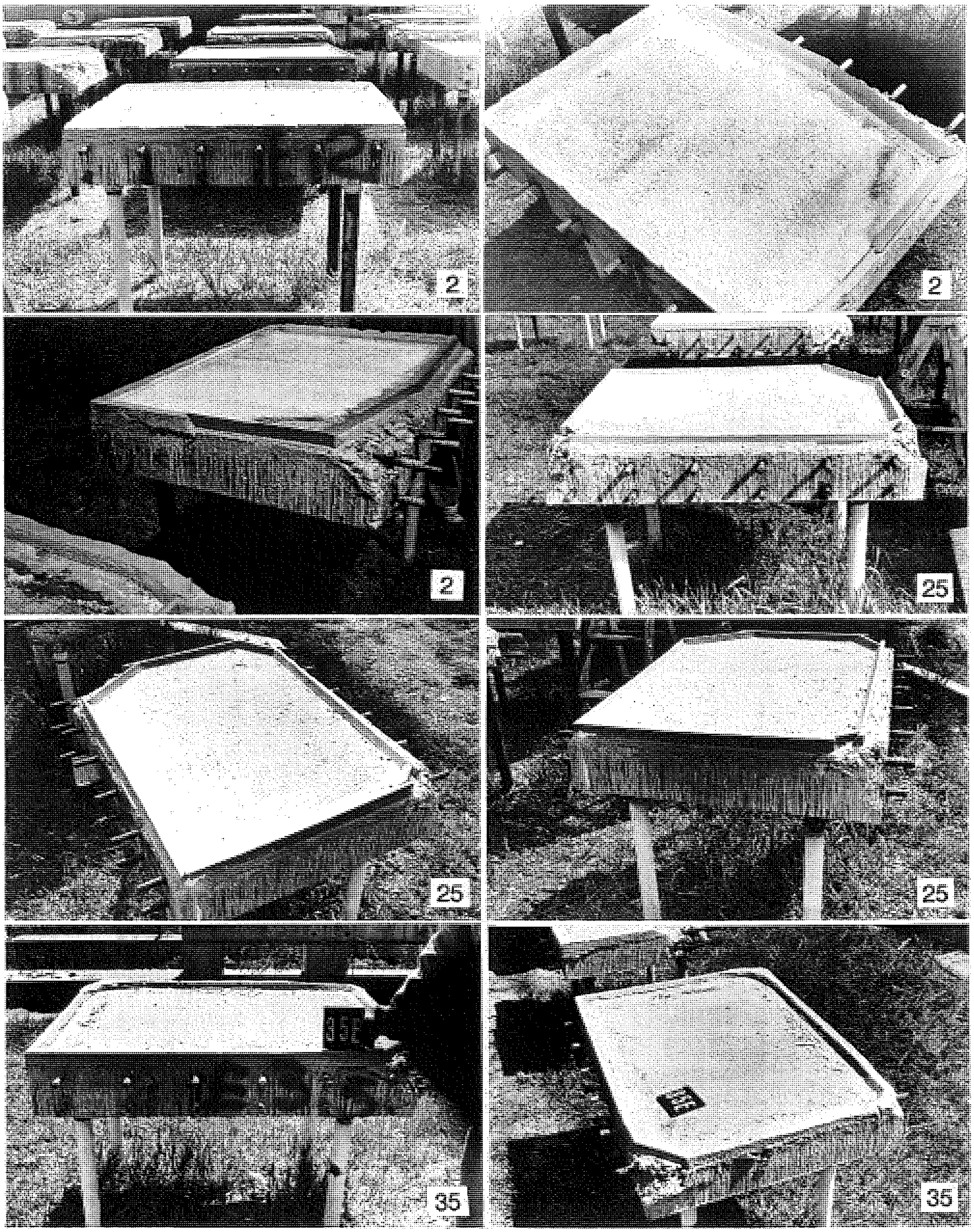


Figure 8 Continued. Appearance of epoxy coated field exposure specimens after 13 years of exposure. Green epoxy coating over white metal blast.

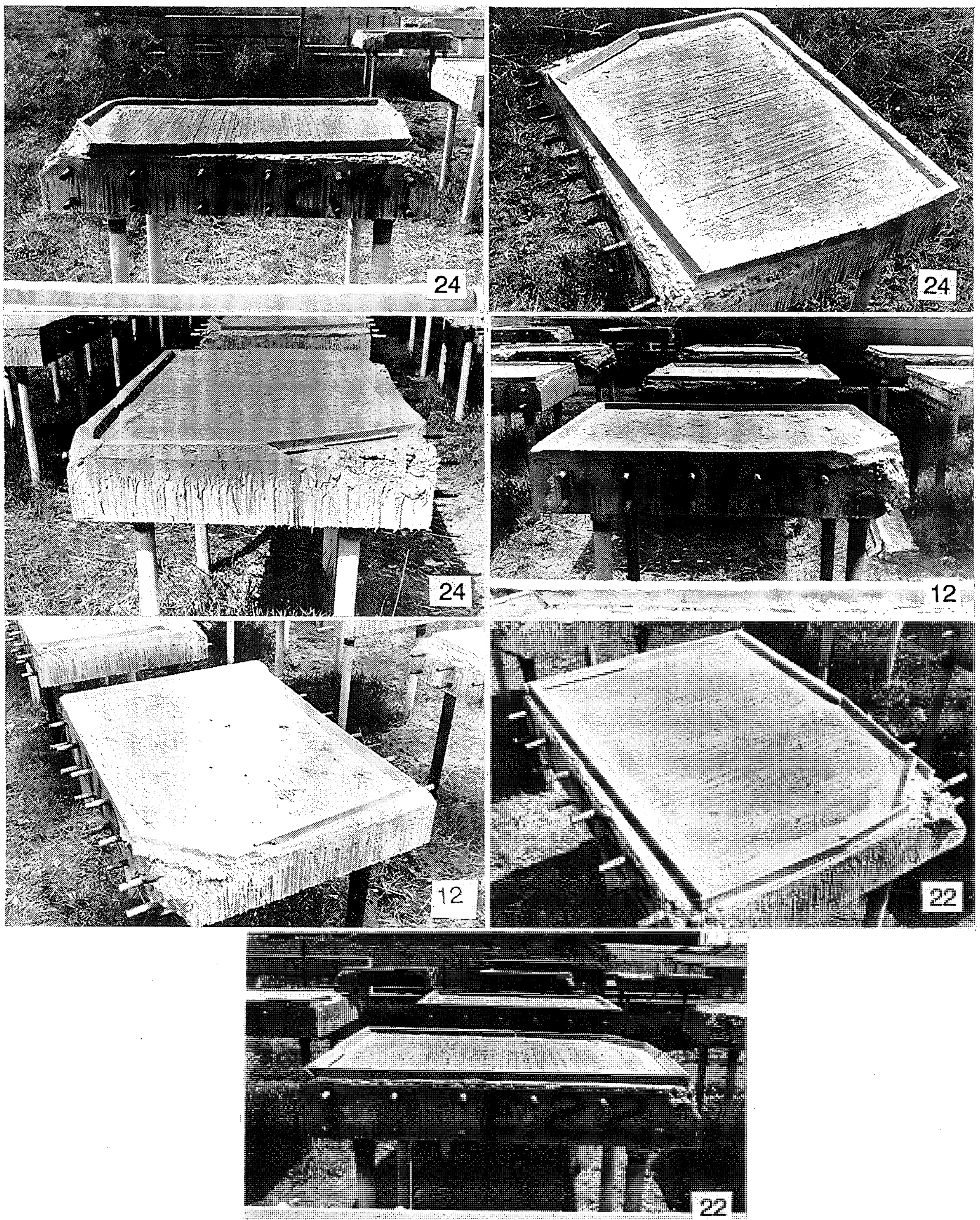


Figure 8 Continued. Appearance of epoxy coated field exposure specimens after 13 years of exposure. Green epoxy coating over white metal blast--uncoated chairs used between top and bottom mats.

Many of the slabs show what is apparently freeze/thaw deterioration at either corners, edges or both.

In many instances, the concrete has separated and fallen at one or more end rows of the transverse reinforcement. This deterioration appears to be more related to the ending point of the longitudinal reinforcement, which does not extend past the transverse reinforcement, than anything else. Without the longitudinal support of possible tensile loading any corrosion of these bars or ice forming in a crack over these bars could result in the observed damage. Damage to the central portions of the slabs is, typically, more important in evaluating the performance of the different reinforcements.

In general, slabs made from pour No. 2 demonstrate the most noticeable deterioration.

The galvanized specimens (i.e., both top and bottom mats galvanized) performed better than the 1/2 galvanized specimens (i.e., only top mat galvanized). Corrosion problems in the bottom mat were evident for the 1/2 galvanized specimens.

For the gray epoxy coated specimens there was not a great deal of difference in performance between the different surface treatments that were used prior to coating.

For both the red and green epoxy coated specimens there was a noticeable difference between the different surface treatments with the white and near white blast cleaned specimens demonstrating better performance than the commerical blast cleaned specimens.

The red and green epoxy coated specimens are, based on visual observation (i.e., photos of 1987), competitive with the galvanized (i.e., both top and bottom mats galvanized) specimens.

Half-Cell Measurements

While half-cell measurements are not normally associated with epoxy coated reinforcement, the ends of the individual reinforcement bars were readily accessible allowing measurement for individual bars even when the epoxy coating was still intact and electrically isolating each bar within the concrete. Initial measurements were, however, first made after 12 years of weathering at which point many of the bars were already interconnected via either initial holidays in the coatings at the interface of longitudinal and transverse bars or subsequent corrosion of these interface surfaces. (Approximately 50 percent of the epoxy coated bars on an actual bridge deck, a separate research project, that were individually wired to allow future linear polarization measurements were found to be electrically interconnected immediately after the deck was poured despite separation distances of up to 100 ft and the use of coated chairs and insulated tie wire.)

Values for the slabs made from pour No. 2 did not show sufficient variance from the values for the other slabs to justify separate treatment as was done for the visual performance data.

Average half-cell potentials for the epoxy coated reinforcement specimens are recorded in Table 11. All values are greater than the -0.35 v that presumably indicates a 90 percent or greater chance of corrosion occurring.

TABLE 11
HALF-CELL MEASUREMENTS FOR EPOXY COATED FIELD EXPOSURE SPECIMENS

Experimental Details Coating Type	After 12 Years Exposure	
	Half-Cell Potential, negative volts Top Mat	Half-Cell Potential, negative volts Bottom Mat
Uncoated	.47	.50
1/2 Galvanized (Top Mat only)	.55	.47
Galvanized	.50	.49
Gray Epoxy		
Commercial Blast	.54	.56
Near White Blast	.58	.55
White Metal Blast	.58	.48
Red Epoxy		
Commercial Blast	.62	.58
Near White Blast	.62	.61
White Metal Blast	.59	.50
Green Epoxy		
Commercial Blast	.59	.48
Near White Blast	.56	.53
White Metal Blast	.43	.46
White Metal Blast (Uncoated Chairs)	.48	.49

Several trends in the data are apparent.

To the extent that magnitude of half-cell potential can reflect magnitude of corrosion, the epoxy specimens prepared with a white metal blast appear to be performing better than the other degrees of surface treatment although some overlap of the data exists. The red epoxy specimens appear to be corroding slightly faster than the other epoxies. The half-cell values for the uncoated specimens would suggest that they are not corroding any faster than the epoxy coated specimens although this is probably not a fair comparison given the nature of the half-cell measurement and the large differences in available surface area between the two types of specimens.

The differences between half-cell potentials are probably not sufficiently large enough to expect them to reflect actual differences in the performance of the specimens with any degree of certainty. This is especially true when one considers the instantaneous nature of half-cell measurements, and the cumulative nature of corrosion.

The other possible problem areas regarding half-cell measurements mentioned for the 68 F-103 specimens are relevant for these specimens also. If the electrical potential shifts generated by any corrosion activity does affect the readings of an entire slab, this would suggest that the exposed ends of the reinforcement may be dominating the half-cell values. Since corrosion of these areas, which are periodically drenched with saltwater when rainfall overflows the dikes, is relatively uniform among all the specimens; this may help to explain the lack of any really significant differences in the magnitudes of the half-cell potentials despite large differences in overall corrosion.

As mentioned for 68 F-103, half-cell data would normally include equipotential maps and cumulative frequency distributions for all relevant specimens. While this could be done here, the lack of any real variation in magnitude of the values makes such an action essentially pointless. The half-cell values are recorded in Appendix E for those interested in examining them further.

Macrocell Corrosion Current

Macrocell corrosion currents between the top and bottom mats are recorded in Table 12. Given the high variation between the values, averaging did not seem appropriate and therefore the values for each individual slab are given in the table. Where multiple entries occur in the columns the same slab will occupy the same position in the adjacent columns. For this measurement, slabs made from pour No. 2 do not appear to differ markedly from the other slabs. Slabs made from pour No. 2 have been underlined, however, to help highlight this fact since large differences did exist for the visual observations.

Several trends in the data are evident. (It should be kept in mind that these results should be more indicative of what would happen if the top and bottom mats had been electrically connected.)

The red and green epoxy specimens appear to be corroding less than the gray epoxy specimens and may be corroding less than the uncoated and galvanized specimens although there is some overlap of these values.

The gray epoxy specimens appear to be corroding more than either the uncoated or galvanized specimens.

Differences between subsequent (after roughly two years) readings of the same slabs differ by as much as a factor of 20.

TABLE 12
MACROCELL CORROSION CURRENTS FOR EPOXY COATED FIELD EXPOSURE SPECIMENS

Experimental Details Coating Type	After 10 Years Exposure Current, microAmps	After 12 Years Exposure Current, microAmps
Uncoated	296, 143	156, 638
1/2 Galvanized (Top Mat only)	255, 242, 70	819, 5250, 443
Galvanized	26, 113, 175	323, 600, 87
Gray Epoxy		
Commercial Blast	259, 614, 678	259, 813, 662
Near White Blast	911, 1750, 154	1832, 1782, 36
White Metal Blast	1080, 250, 734	705, 267, 237
Red Epoxy		
Commercial Blast	35, 69, 16	126, 14, 240
Near White Blast	27. 51, 26	140, 65, 43
White Metal Blast	60, 104, 44	166, 30, 57
Green Epoxy		
Commercial Blast	226, 5, 14	14, 298 319
Near White Blast	71, 63, 109	23, 51, 22
White Metal Blast	38, 16, 5	431, 138, 237
White Metal Blast (Uncoated Chairs)	171, 30, 19	8, 308, 9

The same problems that apply to macrocell corrosion current measurements that were mentioned for 68 F-103 also apply here and hence caution should be exercised before accepting results generated from just this source of information.

The same problems with respect to surface runoff and salt penetration from the sides and possibly bottom of the slabs that applied for 68 F-103 also apply to these slabs.

Electrical Resistance

Electrical resistance measurements for the epoxy coated specimens reflect both the condition of the concrete, as discussed for the galvanized specimens, and the integrity of the epoxy coating (i.e., original holidays and rust or mechanically generated breaks in the coating). As can be seen from the variation of values for the galvanized reinforcement specimens (Table 5) compared to those for the epoxy coated specimens (Table 13), the integrity of the epoxy coating has the biggest influence on electrical resistance magnitude.

Average electrical resistance measurements for the epoxy coated reinforcement specimens are recorded in Table 13. (Values for pour No. 2 were not sufficiently different to justify separating them from the rest of the data.)

TABLE 13
AVERAGE dc ELECTRICAL RESISTANCE MEASUREMENTS BETWEEN THE TOP AND BOTTOM REINFORCEMENT MATS FOR EPOXY COATED FIELD EXPOSURE SPECIMENS

Experimental Details Coating Type	After 10 Years Exposure Resistance, ohms	After 12 Years Exposure Resistance, ohms
Uncoated	16	12
1/2 Galvanized (Top Mat only)	24	17
Galvanized	23	15
Gray Epoxy		
Commercial Blast	18	15
Near White Blast	24	16
White Metal Blast	20	19
Red Epoxy		
Commercial Blast	84	40
Near White Blast	97	53
White Metal Blast	150	83
Green Epoxy		
Commercial Blast	134	53
Near White Blast	122	63
White Metal Blast	262	151
White Metal Blast (Uncoated Chairs)	263	163

Here, as for the galvanized specimens in 68 F-103, the galvanized specimens have higher resistances than the uncoated specimens. While the differences are not great, the same implications apply.

The resistance values for the gray epoxy specimens are only slightly different from those for the uncoated specimens suggesting that the gray epoxy has almost completely disintegrated.

The red epoxy specimens are intermediate between the uncoated specimens and the green specimens suggesting that green epoxy is holding up at least a little bit better.

Reinforcement Corrosion

Average corrosion figures for the reinforcement are recorded in Table 14. (Values for pour No. 2 were not sufficiently different to justify separating them from the rest of the data.) This represents what is apparently the best evidence of reinforcement coating performance.

The most interesting result is the performance of the gray epoxy coated specimens which had more corrosion than the uncoated reinforcement. Several possible scenarios may help to explain this unusual result. To perform worse than the uncoated reinforcement the epoxy coating must somehow be aiding in the corrosion process. If not properly bonded to

TABLE 14
APPROXIMATE AREAS OF SURFACE CORROSION (AND EPOXY COATING DISTRESS)
ON THE REINFORCEMENT USED IN THE EPOXY COATED FIELD EXPOSURE SPECIMENS

Experimental Details	After 13 Years Exposure	
Coating Type	Top Mat, percent	Bottom Mat, percent
Uncoated	45	65
1/2 Galvanized (Top Mat only)	5	35
Galvanized	5	15
Gray Epoxy		
Commercial Blast	95	90
Near White Blast	95	80
White Metal Blast	95	90
Red Epoxy		
Commercial Blast	50	50
Near White Blast	35	25
White Metal Blast	35	30
Green Epoxy		
Commercial Blast	50	40
Near White Blast	25	40
White Metal Blast	20	10
White Metal Blast (Uncoated Chairs)	20	25

the steel substrate the epoxy might allow a more effective channel for salt impregnated water to reach greater surfaces of steel and remain there once the solution has reached holidays in the epoxy coating. Or alternately, the coating might actually be cathodic to the steel thereby allowing perferential corrosion of the steel at all initial holidays and rapid undercutting of the epoxy coating. Surface preparation had, apparently, no effect on the performance of the gray epoxy coating.

None of the epoxy coatings when applied after only a commercial blast performed markedly better than the uncoated reinforcement.

The green epoxy coated reinforcement appears to have performed slightly better than the red epoxy coated reinforcement. Surface preparation prior to coating played a significant role in how well these coatings held up; the better the degree of 'cleaning' of the surface the better the corrosion performance.

Most of the corrosion of the reinforcement with green epoxy coating occurred adjacent to the exposed ends. The red epoxy coated reinforcement, typically, had only half or slightly more of its corrosion near the exposed ends. Corrosion for the gray epoxy coated specimens typically extended from one exposed end of the reinforcement to the other with only occasional islands of intact epoxy. If the reinforcement ends had not been exposed, the ordering of the performance of the epoxy coated specimens probably would have remained unchanged but the differences between the coatings would have, most likely, been more dramatic. The corrosion from the ends being like adding a large number of similar magnitude to a batch of numbers of different magnitude thereby masking the original extent of the differences between the numbers.

Interestingly, the galvanized specimens appear to have performed better than the epoxy coated specimens. This is probably due to the superior corrosion performance of galvanized coated steel in the atmosphere and the sacrificial nature of the zinc coating (i.e., preventing undercutting of the coating). Corrosion of the galvanized specimens did not, in general, proceed as far into the concrete from the exposed ends as occurred for the epoxy coated specimens.

In a number of cases, more corrosion has occurred on the bottom mat than the top mat. This is to some extent to be expected since the overflow water from the top has applied salt to the edges of the specimens allowing higher salt concentrations at the edges. For the bottom mat especially, where little or no salt has penetrated the surface to the bottom mat, a 'macrocell' would be generated within the mat with the salted areas as anode. For the top mat, the differences in salt concentration would be more uniform with less intense 'macrocells' being generated.

Miscellaneous

While not intended as part of the original work, an interesting result with respect to reinforcement deformation patterns was noticed for the epoxy coated specimens. A number of different patterns were used on the bars in this project. The pattern that had discontinuous deformations (i.e., longitudinally) performed markedly better than those with continuous deformations under the same conditions. Several factors could help to explain this observed difference. The deformations create a bend in the surface that may be more difficult to properly clean (i.e., sandblasting or mechanical rust removal) prior to the epoxy coating. The bend may help to create a gap under the coating due to shrinkage as the coating cures, or as differential thermal expansion/contraction loosens the bond between the coating and steel substrate. Any remaining rust or gap at the bend of the deformations could allow easier penetration of the necessary ingredients for corrosion along the reinforcement once these ingredients have found access to a break in the coating.

All of the problems with specimen design and result interpretation discussed under the Miscellaneous heading for 68 F-103 except for the galvanic coupling problem, are relevant for these specimens as well.

Results Summary

Galvanized (68 F-103)

Increased depth of cover, increased cement content, and decreased water/cement ratio all increased the time necessary for chloride penetration to the reinforcement levels and, consequently, increased the time for initiation of corrosion, and decreased the amount of corrosion which could occur within a specified period of time.

Increased depth of cover increases the strength of the cover over the reinforcement that the buildup of rust must exceed before deterioration can occur. Consequently, increased depth of cover increases the time to corrosion damage beyond that associated with just the delay in chloride ion concentration. Increased depth of cover and decreased water/cement ratio both act to reduce the number of cracks that can allow earlier penetration of salt to greater depths.

Galvanized reinforcement is a feasible and superior alternative to uncoated reinforcement. The extent of superiority of galvanized reinforcement is difficult to judge from the experimental results considering the problems with 'linkage' of the uncoated and galvanized reinforcement. The galvanized reinforcement performed worse than it otherwise would have because of this contact while the uncoated reinforcement performed better.

Epoxy Coated (73 F-131)

Surface preparation (i.e., commercial blast, near white metal blast, and white metal blast) was found to have a significant effect on the performance of epoxy coated reinforcement. In general, the more extensive the degree of surface cleaning prior to coating, the better the epoxy coating performed in both bend testing and long term corrosion testing.

Considerable differences were found to exist between the performance of the different epoxy coatings tested. The gray epoxy coating performed worse than the uncoated reinforcement. The red and green epoxy coatings performed better than uncoated reinforcement. The green epoxy coating performed better than the red epoxy coating.

The galvanized reinforcement performed better than any of the epoxy coatings. This result, however, is partially the result of the exposed ends of the reinforcement in the test slabs where galvanizing has a significant advantage over epoxy coating.

Epoxy coated reinforcement is feasible and the preferred corrosion prevention alternative for use in Michigan's bridges. Epoxy coatings have been used extensively in Michigan bridge decks since 1975. Usage has gradually expanded from just bridge deck mats--top mat first then bottom also--to a number of structural areas that are exposed to traffic-borne salt spray. Current construction specifications also call for the use of epoxy coated reinforcement in splash areas in bridge substructures (bridge railings, front face of abutments, and all pier reinforcement above the footing) and the retaining walls (front face) of depressed freeways.

Discussion

Galvanized (68 F-103)

While the galvanized portion of the specimens appeared to perform better than the uncoated portion, there remains some question as to how much better the galvanized reinforcement might actually be. This is especially true in light of the apparent tendency of the galvanized portions of some slabs to deteriorate at a faster rate than the uncoated portions for the later half of the project.

The problem with uncoated reinforcement has been found, in numerous research studies, to be the expansion of the corrosion products which eventually exceed the tensile strength of the concrete cover. Zinc corrodes in much the same manner as iron and creates an oxide which is larger than the original metal which creates it. While this oxide may not expand as fast as iron oxide, eventually there will still probably be expansion problems. Some of the zinc oxide may migrate into the surrounding concrete. This is at least partially suggested by the apparent strong bond between the galvanized reinforcement and the concrete. If this is true, then denser, high quality concretes may experience earlier failures with galvanized reinforcement as the oxides build up higher pressures sooner.

Zinc (i.e., galvanizing) has several advantages. Zinc tends to be less corrosive at the alkaline pH's normally found in concrete (pH range of approximately 12 to 13). Above, roughly, a pH of 12.5, zinc reacts by forming soluble zincates ($HZnO_2$) which could probably migrate through the concrete pore structure without building up corrosive pressures. The hydrated oxide ($Zn(OH)_2$) formed when zinc behaves in the normally desired sacrificial manner acts as an electrical insulator which may be forming a barrier layer preventing further corrosion at that particular active corrosion location.

While some circumstances appear to place zinc at a disadvantage, these conditions do not appear to be relevant for a highway environment. High temperatures (i.e., greater than roughly 140 F) can reverse the polarity of zinc resulting in a less favorable oxide (i.e., ZnO, a semiconductor which can be noble to both zinc and steel). This does not appear to be relevant for Michigan's highway environment where bridge deck temperatures rarely exceed 120 F. While the presence of relatively high levels of carbonates and nitrates can also favor the creation of ZnO, neither would normally be present at high levels in standard concrete (nitrate based accelerator admixtures excepted) and the presence of chlorides tends to reverse this effect. (Carbonation of concrete occurs gradually as carbon dioxide from the atmosphere converts the calcium hydroxide of the pore solution to calcium carbonate, but this progresses, in general, at a much slower rate of advance than the penetration of chloride ions.)

Even with the problems in experiment design, it would be safe to say that the extra service life potentially provided by the galvanizing would far outweigh its modest increase in cost of an entire structure. Galvanized reinforcement costs roughly 1.65 times as much as uncoated reinforcement (1991 prices to MDOT) but the cost of the reinforcement in a bridge is a very small portion of the total cost.

Epoxy Coated (73 F-131)

In theory, epoxy coating should have a great advantage over galvanizing. Zinc corrodes, with all the problems of an expanding oxide. Epoxy establishes a barrier that should block the penetration of the ingredients (i.e., oxygen, water) necessary for corrosion. Obviously, what happens in the real world can be a little more complicated, as evidenced by one of the trial epoxy coatings actually performing worse than uncoated reinforcement.

An epoxy coating is only as good as its ability to perform as a barrier. If the epoxy coating has holidays that will allow salt and water exposure to the bare steel, its ability to function is reduced. If the epoxy coating further does not adhere well to the metal substrate, corrosion, once started, may proceed more rapidly along the reinforcement. If the epoxy coating actually has gaps between itself and the steel, corrosion may even proceed faster with a coating present than without one.

While the epoxy coatings evaluated here were some of the earliest used on reinforcement and the results may not accurately reflect the problems with the latest formulations and production techniques, there is some evidence to suggest that problems may still exist with even more current epoxies. Some of the latest work by Ken Clear (see Bibliography) suggests that there may be vast differences in the functional performance of epoxy coatings despite these coatings meeting current specifications.

While the galvanized reinforcement specimens experienced less corrosion than any of the epoxy coated reinforcement specimens, this is probably largely due to the exposed ends of the reinforcement, which were more susceptible to corrosion for the epoxy coated reinforcement. This allowed corrosion to penetrate further into the slabs with epoxy coated reinforcement. If one looks at the corrosion that occurred in just the central portions of the slabs, the green epoxy (white metal blast) was roughly competitive with the galvanized slabs (the others were not).

The galvanized reinforcement also had an added advantage in that the isolation of the top and bottom mats reduced significantly the possible magnitude of macrocell corrosion effects (for the top mat anyway). Since both anode and cathode (i.e., mats isolated) must be in the same mat and the salt concentration differences for the top mat alone are much less than the differences between the top and bottom mats that would normally be the macrocell driving force.

While the isolation of the top and bottom mats would help reduce corrosion for the epoxy coated specimens, the effects would not be as great due to the more limited size of the anode and cathode (i.e., bare steel).

Realistic differences between the relative performance of galvanized and epoxy coated reinforcement are hard to judge from the data available from this project. The work of others suggests that concrete made with galvanized reinforcement may last roughly twice as long as that made with uncoated reinforcement. Epoxy coated reinforcement has, typically, been found to give even better performance results than galvanized reinforcement.

Implications

While there is some evidence to suggest that galvanized reinforcement may be superior to epoxy coated reinforcement; the uncertain nature of these results, combined with the more appealing corrosion theory behind epoxy coatings, and the current higher cost for galvanizing do not favor a recommendation for the use of galvanizing instead of epoxy coating. Some caution in the selection of an epoxy coating and/or fabricator is advisable, however.

Future Work

Given the problems with vast differences in the performance of epoxy coatings observed for this project, as well as the apparent differences recently observed by Ken Clear on newer coatings, it would appear advisable to establish a quicker testing procedure to determine the relative potential life of present day coatings. A tentative research proposal has been written to help establish an evaluation procedure for epoxy coated reinforcement used on Michigan jobs. If sufficient differences between coatings are found, an approved vendor list will be established to ensure that inferior materials are not used in Michigan's bridges.

Bibliography

Arnold, C. J., "Galvanized Steel Reinforced Concrete Bridge Decks (Progress Report)," Research Report No. R-1033, Michigan Department of Transportation, December 1976.

Arnold, C. J., "Epoxy Resin Coated Reinforcing Steel (Construction and Progress Report)," Research Report No. R-1067, Michigan Department of Transportation, July 1977.

Clear, K. C., "Time to Corrosion of Reinforcing Steel in Concrete Slabs: Vol. 1, Effect of Mix Design and Construction Parameters," Interim Report FHWA-RD-73/52, Federal Highway Administration, 1976.

Clear, K. C., "Time to Corrosion of Reinforcing Steel in Concrete Slabs: Vol. 4, Galvanized Reinforcing Steel," Report No. FHWA-RD-82/028, Federal Highway Administration, 1981.

Clear, K. C., "Effectiveness of Epoxy Coated Reinforcing Steel," Concrete Reinforcing Steel Institute, December 1991.

Clear, K. C., "Effectiveness of Epoxy Coated Reinforcing Steel," Memo to Clients and Associates Kenneth C. Clear, Inc., January 1992.

Gibson, F. W., Editor, "Corrosion, Concrete, and Chlorides--Steel Corrosion in Concrete: Causes and Restraints," American Concrete Institute, Detroit, Michigan, 1987.

Lauer, G., and Mansfeld, F., Corrosion, Vol. 26, 1970, p. 504.

McCrum, R. L., "Performance of Stainless Steel vs. Epoxy Coated Reinforcing Steel--Interim Report," Research Report (in progress), Michigan Department of Transportation.

Uhlig, H. H., Revie, R. W., "Corrosion and Corrosion Control," John Wiley & Sons, New York, 1985.

Virmani, Y. P., Clear, K. C., "Time to Corrosion of Reinforcing Steel in Concrete Slabs; Vol. 5 Calcium Nitrite Admixture or Epoxy-Coated Reinforcing Bars as Corrosion Protection Systems," Report No. FHWA-RD-83/012, Federal Highway Administration, September 1983.

Appendix A

Computer program for simplifying drawing of equipotential and frequency distribution plots of half cell readings (satisfies the information requirements of ASTM C876-80). This program has been used on IBM XT and AT class microcomputers and is written in Microsoft fortran.

This program was originally written for use with our experimental bridge decks, but is equally useful for the simulated bridge deck slabs with only minor modification to the data input. There are sufficient comments and variable identification (variable definitions follow the program listing) to allow user modifications to suit other applications. The variables that control plot dimensions and equipotential intervals can be placed in a file outside of the program to make quick changes to the program output that do not require recompilation of the program. As presently configured the program requires a printout capability of 220 columns by 66 rows, but this can be easily modified to match other printers by anyone familiar with fortran (alternately, most laser printers have at least one font that will adapt to this printout).

Source and/or text (i.e. compiled) copies (on floppy disks) of this program can be made available to interested parties upon request.

A source compilation listing (and variable definition table) follows (starting next page):

```
Line# Source Line          Microsoft FORTRAN Optimizing Compiler Version 4.00

C-    PROGRAM WRITTEN BY RONNIE L. MCCRUM, MICHIGAN DEPARTMENT OF
C-    TRANSPORTATION, P. O. BOX 30049, LANSING, MI 48909.
      PROGRAM EQUPOT
      DIMENSION ALPHA(33,21),BETA(11,21),EQU(4),
     -FFF(200),IOPT(5),IERR(5),
     -RANK(200),SMOD(20),PLOTR2(37)
      CHARACTER A(5)*1,INFO(72)*4,TDIR(3)*8,DATE*8,PLOTR1(37)*1,
     -PLOT(211,55)*1,PLOT2(210,60),FPLOT(32)*1,FPLOT2(26)*1,
     -SPLOT(25)*1,SPLOT2(50)*1,ANUMO(10)*1,PLTSYM(10)*1,PLTVAL(30)*1
      REAL LOW,LOW1,LOW2,LABELX(63),LABELY(33),MEAN,MOD(200,2),MODE
      INTEGER SPAN
      LOGICAL LOGIC,LOGIC2
      COMMON /EQUDAT/ A,ANUMO,PLOTR2
      DATA PLOTR1/'$','A','B','C','D','E','F','G','H','I','J',
     -'K','L','M','N','O','P','Q','R','S','T','U','V',
     -'W','X','Y','Z','1','2','3','4','5','6','7','8','9','0'/
      DATA FPLOT/'H','A','L','F',' ',' ','C','E','L','L',' ',' ',
     -  'P','O','T','E','N','T','I','A','L',' ',' ','I','N',' ',
     -  ' ','V','O','L','T','S'/
      DATA FPLOT2/'C','U','M','U','L','A','T','I','V','E',' ',' ','F',
     -  'R','E','Q','U','E','N','C','Y',' ',' ','(','%',')'/
      DATA SPLOT/'F','E','E','T',' ',' ','F','R','O','M',' ',' ',
     -  'C','U','R','B',' ',' ',' ',' ',' ',' ',' ',' ',' '/
      DATA SPLOT2/'F','E','E','T',' ',' ','F','R','O','M',' ',' ',
     -  'E','N','D',' ',' ','O','F',' ',' ','E','X','P','E','R','I',
     -  'M','E','N','T','A','L',' ',' ','S','E','C','T','I','O','N',
     -  ' ',' ',' ',' ',' ',' ',' ',' '/
C-
C-          FILE 1 -- DISK DEBUG AND PRINT FILE
C-          FILE 5 -- DISK DATA INPUT FILE
C-
      OPEN(UNIT=1,FILE='OUTPUT.LST',STATUS='UNKNOWN',ACCESS='SEQUENTIAL
     -,FORM='FORMATTED')
      OPEN(UNIT=5,FILE='RLMEQU.DAT',STATUS='OLD',ACCESS='SEQUENTIAL',
     -FORM='FORMATTED')
C-
C-     WHOLE BRIDGE (DATA FILE) PARAMETER INITIALIZATION
C-
      BLANK=' '
      BLANK3='   '
      COLONS=':'
      EQ1='='
      GRHVAL=3.0
      MINUS='-'
      PERIOD='.'
      PLUS='+'
      SYM='$'
      SYM2='M'
      SYM3='O'
      SROW=10.0
      SCOL=20.0
      INTVAX=5
      INTVAY=5
      P1DX=211
      P1DY=55
      P1DYP1=P1DY+1
```

```
      P2DX=210
      P2DY=60
      P2DYP1=P2DY+1
      ILABX=63
      ILABY=33
C-
C-     READ DESCRIPTIVE BRIDGE INFO--ONLY ONCE / BRIDGE
C-
      READ(5,1) (INFO(I),I=1,72)
1     FORMAT(18A4)
C-
C-     READ DATA SET
C-
C-     READ INTRODUCTORY INFORMATION
2     READ(5,3,END=1000)SPAN,TDIR,DATE,NCOL,NROW,TEMP
3     FORMAT(I1,3A4,A8,2I2,F3.0)
C-
C-         READ SELECTED OPTIONS
C-
C-      READ(5,4)IOPT
C-4     FORMAT(3I1)
      DO 10 I=1,NCOL
C-
C-         READ DATA AS NUMERIC VALUES--FOR CALCULATIONS
C-
      READ(5,5)(BETA(K,I),K=1,NROW)
5     FORMAT(24F3.2)
10    CONTINUE
C-
C-         CORRECT NUMERIC DATA FOR TEMPERATURE
C-
C-         BY PASS IF TEMP IS NOT AT LEAST 10 DEGREES GREATER OR LESS
C-         THAN 72 DEGREES F OR TEMP IS NOT WITHIN THE RANGE OF 32
C-         120 DEGREES F
C-
      IDIFF=ABS(72-TEMP)
      IF(TEMP.LT.32.0.OR.TEMP.GT.120.0.OR.IDIFF.LT.10.0)GOTO 35
      DO 30 I=1,NCOL
      DO 30 J=1,NROW
      BETA(J,I)=BETA(J,I)+.0005*(72.0-TEMP)
30    CONTINUE
C-
C-      CREATE ALPHANUMERIC DATA VALUES FOR INCLUSION IN GRAPH
C-      ARRAY
C-
35    DO 40 I=1,NCOL
      DO 40 J=1,NROW
      CALL BNUMO(BETA(J,I),3)
      ALPHA(3*J-2,I)=A(1)
      ALPHA(3*J-1,I)=A(2)
      ALPHA(3*J,I)=A(3)
40    CONTINUE
C-
C-     SPAN (DATA SET) PARAMETER INITIALIZATION
C-
      DO 50 I=1,20
```

```
         SMOD(I)=0.0
50       CONTINUE
55       ROW=SROW
         COL=SCOL
         ITOT=NCOL*NROW
         TOT=ITOT
         ISPLIT=0
         IERR(1)=0
         IERR(2)=0
         IERR(3)=0
         IERR(4)=0
         IERR(5)=0
         DO 90 I=1,ITOT
         MOD(I,1)=0.0
         MOD(I,2)=0.0
         RANK(I)=0.0
90       CONTINUE
C-
C-         CALCULATION OF STANDARD DEVIATION (SD), MEAN, MODE, RANK,
C-         AND FREQUENCY DISTRIBUTION (FFF(I))
C-
         SUM=0.0
         SUM2=0.0
         DO 105 J=1,NCOL
         DO 105 I=1,NROW
         SUM=SUM+BETA(I,J)
         SUM2=SUM2+(BETA(I,J))**2.0
105      CONTINUE
         MEAN=SUM/ITOT
         SD=((SUM2-(SUM*SUM/ITOT))/(ITOT-1))**.500
C-
C-         RANKING OF EQUIPOTENTIAL VALUES
C-
         ICOUNS=0
         DO 110 J=1,NCOL
         DO 110 I=1,NROW
         ICOUNS=ICOUNS+1
         RANK(ICOUNS)=BETA(I,J)
         DO 109 K=1,ICOUNS
         IF(K.EQ.1)GOTO 109
         IF(RANK(K-1).LT.RANK(K))GOTO 109
         DO 108 K2=0,K-2
         IF(RANK(K-K2).GE,RANK(K-K2-1))GOTO 108
         TEMP1=RANK(K-K2)
         RANK(K-K2)=RANK(K-K2-1)
         RANK(K-K2-1)=TEMP1
108      CONTINUE
109      CONTINUE
110      CONTINUE
C-
C-         FREQUENCY DISTRIBUTION OF EQUIPOTENTIAL VALUES
C-
         DO 120 I=1,ITOT
         ABC=I
         FFF(I)=ABC/(TOT+1.0)*100.0
120      CONTINUE
```

```
C-
C-     MODE VALUE CALCULATION
C-
      I=1
      I2=1
131   J=0
      MOD(I2,1)=RANK(I)
132   I=I+1
      J=J+1
      IF(MOD(I2,1).EQ.RANK(I))GOTO 132
      MOD(I2,2)=J
      I2=I2+1
      IF(I.GT.ITOT)GOTO 133
      GO TO 131
133   MODEN=0
      DO 135 I=1,I2
      IF(MOD(I,2).GT.MODEN)JK=I
      IF(MOD(I,2).GT.MODEN)MODEN=MOD(I,2)
135   CONTINUE
      MODE=MOD(JK,1)
      J=0
C-
C-        OTHER VALUES OCCURRING WITH THE SAME FREQUENCY AS 'MODE'
C-        STORED IN SMOD ARRAY
C-
      DO 136 I=1,I2
      IF(MOD(I,2).NE.MODEN)GO TO 136
      IF(MOD(I,1).EQ.MODE)GO TO 136
      J=J+1
      SMOD(J)=MOD(I,1)
136   CONTINUE
C-
C-        EQUIPOTENTIAL GRAPH INTERVAL SELECTION--EITHER .025, .05,
C-        OR .10 VOLT INTERVALS  SELECTED BASED ON TOTAL NUMBER OF
C-        INTERVALS THAT WOULD BE CREATED (GRAVAL) FOR EACH GRAPH
C-
      TEST=(RANK(ITOT)-RANK(1))
      TEST1=TEST/.025
      TEST2=TEST/.050
      TEST3=TEST/.100
      TERVAL=0.0
      IF(TEST1.GE.GRHVAL)TERVAL=1.0
      IF(TEST2.GE.GRHVAL)TERVAL=2.0
      IF(TEST3.GE.GRHVAL)TERVAL=4.0
      IF(TERVAL.EQ.0.0.AND.TEST1.GE.2.0)TERVAL=1.0
C-
C-        AT LEAST TWO INTERVALS MUST BE PRESENT--OTHERWISE SKIP  GRAPH
C-
      IF(TERVAL.EQ.0.0)IERR(1)=1
      IF(IERR(1).GT.0)GO TO 400
      DO 205 I=1,37
      IF(PLOTR2(I).GE.RANK(1))GO TO 202
      GO TO 205
C-
C-         DETERMINE POINTERS TO BEGINNING & ENDING PLOT INTERVALS
C-         WITHIN PLOTER ARRAY
```

```
C-
 202  ISAVE=I
      GO TO 201
 205  CONTINUE
 201  ITERVL=TERVAL
      SAVE=ISAVE
      TEST4=(ISAVE-1)/ITERVL
      TEST5=(SAVE-1.0)/TERVAL
      IF((TEST5-TEST4).GT.0.0)GO TO 207
      GO TO 208
 207  ISAVE=ISAVE+1
      GO TO 201
 208  ISAVE2=ISAVE+ITERVL
      GO TO 210
 209  ISAVE2=ISAVE2+ITERVL
 210  IF(PLOTR2(ISAVE2).LE.RANK(ITOT))GO TO 209
      ISAVE2=ISAVE2-ITERVL
C-
C-      ARRAYS TO PRINT PLOT SYMBOLS AND VALUES
C-
      DO 214 I=1,10
      PLTSYM(I)= BLANK
      PLTVAL(3*I-2)= BLANK
      PLTVAL(3*I-1)= BLANK
      PLTVAL(3*I)= BLANK
 214  CONTINUE
      JSMVAL=0
      DO 215 I=ISAVE,ISAVE2,ITERVL
      JSMVAL=JSMVAL+1
      PLTSYM(JSMVAL)=PLOTR1(I)
      PLOTMP=PLOTR2(I)
      CALL BNUMO(PLOTMP,3)
      PLTVAL(3*JSMVAL-2)=A(1)
      PLTVAL(3*JSMVAL-1)=A(2)
      PLTVAL(3*JSMVAL)=A(3)
 215  CONTINUE
C-
C-      PREPARATION OF EQUIPOTENTIAL GRAPH ARRAY
C-
C-      DETERMINE IF SPLIT GRAPH CAN BE USED
C-
      IF(NCOL.GT.21.OR.NROW.GT.11) IERR(2)=1
      IF(IERR(2).GT.0)GO TO 400
      IF(NCOL.GT.11.AND.NROW.LE.3)ISPLIT=1
      IF(ISPLIT.GT.0)GO TO 220
C-
C-      ROW & COLUMN SPACING CHANGES IF NUMBER OF DATA ELEMENTS
C-      EXCEEDS DEFAULT LIMITS
C-
      IF(NROW.GT.6)ROW=ROW/2.0
      IF(NCOL.GT.11)COL=COL/2.0
      IF(NCOL.GT.11.AND.NROW.LE.6)ROW=ROW/2.0
      IF(NROW.GT.6.AND.NCOL.LE.11)COL=COL/2.0
 220  IROW=ROW
      ICOL=COL
C-
```

```
C-      CLEARING OF ARRAY FOR NEXT GRAPH
C-
      DO 221 I=1,P1DX
      DO 221 J=1,P1DY
      PLOT(I,P1DYP1-J)=BLANK
221   CONTINUE
      DO 222 J=5,P1DY,IROW
      DO 222 I=10,P1DX-1
      PLOT(I,P1DYP1-J)=MINUS
222   CONTINUE
      DO 223 I=10,P1DX-1,ICOL
      DO 223 J=5,P1DY
      PLOT(I,P1DYP1-J)=COLONS
      IF(ISPLIT.GT.0.AND.J.GE.26.AND.J.LE.34)PLOT(I,P1DYP1-J)=BLANK
223   CONTINUE
C-
C-      PLACING OF DATA VALUES IN ARRAY
C-
      IEMI=8
      IEMJ=5
      IEMI2=8
      IEMJ2=35
      L=NCOL
      L2=0
      IF(ISPLIT.LE.0)GO TO 235
      L=NCOL-10
      L2=10
      DO 231 I=1,11
      DO 231 J=1,NROW
      JEM=IEMJ2+(J-1)*IROW
      IEM=IEMI2+(I-1)*ICOL
      DO 231 K=1,3
      PLOT(IEM+K,P1DYP1-JEM)=ALPHA(3*(J-1)+K,I)
231   CONTINUE
235   DO 236 I=1,L
      DO 236 J=1,NROW
      JEM=IEMJ+(J-1)*IROW
      IEM=IEMI+(I-1)*ICOL
      IF(IEM.GE.P1DX)GO TO 236
      DO 236 K=1,3
      PLOT(IEM+K,P1DYP1-JEM)=ALPHA(3*(J-1)+K,I+L2)
236   CONTINUE
C-
C-      LABELLING OF X & Y AXIS
C-
      DO 237 I=1,25
      PLOT(3,18+I)=SPLOT(I)
      IF(ISPLIT.GT.0)PLOT(75+I,25)=SPLOT2(I)
      IF(ISPLIT.GT.0)PLOT(100+I,25)=SPLOT2(I+25)
      PLOT(75+I,55)=SPLOT2(I)
      PLOT(100+I,55)=SPLOT2(I+25)
237   CONTINUE
C-
C-      GENERATION OF NUMERICAL SPACING LABELS FOR X AND Y AXIS
```

```
C-
C-
C-      CLEARING OF LABEL ARRAYS
C-
      DO 239 I=1,ILABY
      LABELY(I)=BLANK
239   CONTINUE
      DO 240 I=1,ILABX
      LABELX(I)=BLANK
240   CONTINUE
C-
C-      Y -- AXIS
C-
      DO 241 I=1,NROW
      YAXIS=(I-1)*INTVAY
      CALL BNUMO(YAXIS,3)
      LABELY(3*I-2)=A(1)
      LABELY(3*I-1)=A(2)
      LABELY(3*I)=A(3)
241   CONTINUE
C-
C-      X -- AXIS
C-
      DO 242 J=1,NCOL
      XAXIS=(J-1)*INTVAX
      CALL BNUMO(XAXIS,3)
      LABELX(3*J-2)=A(1)
      LABELX(3*J-1)=A(2)
      LABELX(3*J)=A(3)
242   CONTINUE
C-
C-      NUMERICAL SPACING PLACED IN GRAPH ARRAY
C-
      J=3
      JI=0
      IF(ISPLIT.GT.0)JI=10
250   DO 251 I=8,208,ICOL
      JI=JI+1
      PLOT(I,P1DYP1-J)=LABELX(3*JI-2)
      PLOT(I+1,P1DYP1-J)=LABELX(3*JI-1)
      PLOT(I+2,P1DYP1-J)=LABELX(3*JI)
251   CONTINUE
      IF(ISPLIT.LE.O.OR.J.GT.15)GO TO 252
      JI=0
      J=33
      GO TO 250
252   JI=0
      I=5
      DO 253 J=5,P1DY,IROW
      IF(ISPLIT.GT.O.AND.J.EQ.35)JI=0
      JI=JI+1
      PLOT(I,P1DYP1-J)=LABELY(3*JI-2)
      PLOT(I+1,P1DYP1-J)=LABELY(3*JI-1)
      PLOT(I+2,P1DYP1-J)=LABELY(3*JI)
253   CONTINUE
C-
```

```
C-        PLACE EQUIPOTENTIAL VALUE SYMBOLS ON A GRID BY GRID BASIS
C-
C-        PICK GRID CORNER VALUES
C-
      ISTAR2=10
      JSTAR2=5
      NTCOL=NCOL
      IF(ISPLIT.GT.0)NTCOL=11
      K1=1
      IF(ISPLIT.GT.0)JSTAR2=35
300   DO 399 K=K1,NTCOL-1
      ISTAR=ISTAR2+(K-K1)*ICOL
      DO 395 L=1,NROW-1
      JSTAR=JSTAR2+(L-1)*IROW
      EQU(1)=BETA(L,K)
      EQU(2)=BETA(L+1,K)
      EQU(3)=BETA(L+1,K+1)
      EQU(4)=BETA(L,K+1)
C-
C-        PICK HIGH & LOW VALUES FOR EACH GRID
C-
      HIGH=EQU(1)
      LOW=EQU(1)
      DO 310 IN=2,4
      IF(HIGH.LT.EQU(IN))HIGH=EQU(IN)
      IF(LOW.GT.EQU(IN))LOW=EQU(IN)
310   CONTINUE
      DO 390 INC=ISAVE,40,ITERVL
C-
C-        BYPASS PLOTTING INTERVALS THAT ARE NOT WITHIN THE GRID
C-        LIMITS
C-
      IF(PLOTR2(INC).LT.LOW)GO TO 390
      IF(PLOTR2(INC).GT.HIGH)GO TO 395
C-
C-        ALL FOUR SIDES ONLY DONE ON 1ST GRID SINCE TWO SIDES
C-        OVERLAP WITH OTHER GRIDS
C-
C-        SIDE BETWEEN GRID ELEMENTS 1 & 2
C-
      IF(K.GT.K1)GO TO 320
      CALL HIGHLO(HIGH1,LOW1,EQU(1),EQU(2),TER,LOGIC,INC)
      IF(LOGIC)GO TO 320
      YINC=JSTAR+ABS(EQU(1)-PLOTR2(INC))/TER*ROW
      IXNC=ISTAR
      IYNC=YINC
      IF((YINC-IYNC).GE..5)IYNC=IYNC+1
      PLOT(IXNC,P1DYP1-IYNC)=PLOTR1(INC)
C-
C-        ALL FOUR SIDES ONLY DONE ON 1ST GRID--AS ABOVE
C-
C-        SIDE BETWEEN GRID ELEMENTS 1 & 4
C-
320   IF(L.GT.1)GO TO 321
      CALL HIGHLO(HIGH1,LOW1,EQU(1),EQU(4),TER,LOGIC,INC)
      IF(LOGIC)GO TO 321
```

```
      XINC=ISTAR+ABS(EQU(1)-PLOTR2(INC))/TER*COL
      IYNC=JSTAR
      IXNC=XINC
      IF((XINC-IXNC).GE..5)IXNC=IXNC+1
      PLOT(IXNC,P1DYP1-IYNC)=PLOTR1(INC)
C-
C-      SIDE BETWEEN GRID ELEMENTS 2 & 3
C-
321   CALL HIGHLO(HIGH1,LOW1,EQU(2),EQU(3),TER,LOGIC,INC)
      IF(LOGIC)GO TO 322
      XINC=ISTAR+ABS(EQU(2)-PLOTR2(INC))/TER*COL
      IYNC=JSTAR+ROW
      IXNC=XINC
      IF((XINC-IXNC).GE..5)IXNC=IXNC+1
      PLOT(IXNC,P1DYP1-IYNC)=PLOTR1(INC)
C-
C-      SIDE BETWEEN GRID ELEMENTS 3 & 4
C-
322   CALL HIGHLO(HIGH1,LOW1,EQU(3),EQU(4),TER,LOGIC,INC)
      IF(LOGIC)GO TO 330
      YINC=JSTAR+ABS(EQU(4)-PLOTR2(INC))/TER*ROW
      IXNC=ISTAR+COL
      IYNC=YINC
      IF((YINC-IYNC).GE..5)IYNC=IYNC+1
      PLOT(IXNC,P1DYP1-IYNC)=PLOTR1(INC)
C-
C-      DIAGONAL BETWEEN GRID ELEMENTS 1 & 3
C-
330   CALL HIGHLO(HIGH1,LOW1,EQU(1),EQU(3),TER,LOGIC,INC)
      IF(LOGIC)GO TO 340
      YINC=JSTAR+ABS(EQU(1)-PLOTR2(INC))/TER*ROW
      IYNC=YINC
      XINC=ISTAR+ABS(EQU(1)-PLOTR2(INC))/TER*COL
      IXNC=XINC
      IF((YINC-IYNC).GE..5)IYNC=IYNC+1
      IF((XINC-IXNC).GE..5)IXNC=IXNC+1
      IF(PLOTR2(INC).LT.LOW2.OR.PLOTR2(INC).GT.HIGH2)GO TO 335
      GO TO 339
335   IF(EQU(1).EQ.HIGH1)GO TO 337
      IF((IXNC-ISTAR).LE.10.AND.(IYNC-JSTAR).LE.5.AND.PLOTR2(INC)
     -  .GT.LOW1.AND.PLOTR2(INC).LE.LOW2)GO TO 339
      IF((IXNC-ISTAR).GE.10.AND.(IYNC-JSTAR).GE.5.AND.PLOTR2(INC)
     -  .GE.HIGH2.AND.PLOTR2(INC).LT.HIGH1)GO TO 339
      GO TO 340
337   IF((IXNC-ISTAR).LE.10.AND.(IYNC-JSTAR).LE.5.AND.PLOTR2(INC)
     -  .GE.HIGH2.AND.PLOTR2(INC).LT.HIGH1)GO TO 339
      IF((IXNC-ISTAR).GE.10.AND.(IYNC-JSTAR).GE.5.AND.PLOTR2(INC)
     -  .GT.LOW1.AND.PLOTR2(INC).LE.LOW2)GO TO 339
      GO TO 340
339   IDXNC=IXNC
      IDYNC=IYNC
      DYINC=YINC
      DXINC=XINC
C-
C-      DIAGONAL BETWEEN ELEMENTS 2 & 4
C-
```

```
340   CALL HIGHLO(HIGH2,LOW2,EQU(2),EQU(4),TERPRM,LOGIC2,INC)
      IF(LOGIC2)GO TO 350
      YINC=JSTAR+ABS(EQU(4)-PLOTR2(INC))/TERPRM*ROW
      IYNC=YINC
      XINC=ISTAR+ABS(EQU(2)-PLOTR2(INC))/TERPRM*COL
      IXNC=XINC
      IF((YINC-IYNC).GE..5)IYNC=IYNC+1
      IF((XINC-IXNC).GE..5)IXNC=IXNC+1
      IF(PLOTR2(INC).LT.LOW1.OR.PLOTR2(INC).GT.HIGH1)GO TO 345
      GO TO 349
345   IF(EQU(4).EQ.HIGH2)GO TO 347
      IF((IXNC-ISTAR).GE.10.AND.(IYNC-JSTAR).LE.5.AND.PLOTR2(INC)
     -   .GT.LOW2.AND.PLOTR2(INC).LE.LOW1)GO TO 349
      IF((IXNC-ISTAR).LE.10.AND.(IYNC-JSTAR).GE.5.AND.PLOTR2(INC)
     -   .GE.HIGH1.AND.PLOTR2(INC).LT.HIGH2)GO TO 349
      GO TO 350
347   IF((IXNC-ISTAR).GE.10.AND.(IYNC-JSTAR).LE.5.AND.PLOTR2(INC)
     -   .GE.HIGH1.AND.PLOTR2(INC).LT.HIGH2)GO TO 349
      IF((IXNC-ISTAR).LE.10.AND.(IYNC-JSTAR).GE.5.AND.PLOTR2(INC)
     -   .GE.LOW1.AND.PLOTR2(INC).LT.LOW2)GO TO 349
      GO TO 350
C-
C-        IF SYMBOLS PLACED ON BOTH DIAGONALS, TAKE AVERAGE
C-        POSITION OF THE TWO FOR SINGLE SYMBOL PLACEMENT
C-
349   DXINC2=XINC
      DYINC2=YINC
      IDXNC2=IXNC
      IDYNC2=IYNC
350   IF(DXINC.GT.0.0.AND.DXINC2.GT.0.0)GO TO 353
      IF(DXINC.GT.0.0)GO TO 355
      IF(DXINC2.GT.0.0)GO TO 357
      GO TO 390
353   XINC=(DXINC+DXINC2)/2.0
      IXNC=XINC
      YINC=(DYINC+DYINC2)/2.0
      IYNC=YINC
      IF((XINC-IXNC).GT..5)IXNC=IXNC+1
      IF((YINC-IYNC).GT..5)IYNC=IYNC+1
      PLOT(IXNC,P1DYP1-IYNC)=PLOTR1(INC)
      GO TO 360
355   PLOT(IDXNC,P1DYP1-IDYNC)=PLOTR1(INC)
      GO TO 360
357   PLOT(IDXNC2,P1DYP1-IDYNC2)=PLOTR1(INC)
360   DXINC=0.0
      DXINC2=0.0
390   CONTINUE
395   CONTINUE
399   CONTINUE
      IF(ISPLIT.LE.0.OR.K1.GT.5)GO TO 400
      ISTAR2=10
      JSTAR2=5
      K1=11
      NTCOL=NCOL
      GO TO 300
C-
```

```
C-       PREPARATION OF CUMULATIVE FREQUENCY DISTRIBUTION (CFD)
C-
C-       CLEARING OF ARRAY FOR NEXT GRAPH
C-
400    DO 411 I=1,P2DX
       DO 411 J=1,P2DY
       PLOT2(I,P2DYP1-J)=BLANK
411    CONTINUE
C-
C-       HORIZONTAL AND VERTICAL SPACING FOR ARRAY
C-
       DO 412 I=10,P2DX,20
       DO 412 J=6,P2DY-1
       PLOT2(I,P2DYP1-J)=COLONS
412    CONTINUE
       DO 413 J=6,P2DY-1,12
       DO 413 I=10,P2DX
       PLOT2(I,P2DYP1-J)=MINUS
       IF(J.EQ.18)PLOT2(I,34)=EQ1
       IF(J.EQ.18)PLOT2(I,P2DYP1-J)=EQ1
413    CONTINUE
C-
C-       LABELLING OF X & Y AXIS
C-
       DO 415 I=1,32
       PLOT2(3,12+I)=FPLOT(I)
       IF(I.LE.26)PLOT2(87+I,60)=FPLOT2(I)
415    CONTINUE
C-
C-       NUMERICAL SPACING PLACED IN GRAPH ARRAY
C-
       RJI=-5.0
       J=3
       DO 421 I=8,208,10
       RJI=RJI+5.00005
       CALL BNUMO(RJI,3)
       IF(RJI.GE.100.0)II=I-1
       II=I
       PLOT2(II,P2DYP1-J)=A(1)
       PLOT2(II+1,P2DYP1-J)=A(2)
       PLOT2(II+2,P2DYP1-J)=A(3)
421    CONTINUE
       RJI=-.100
       I=5
       DO 422 J=6,54,6
       RJI=RJI+.100
       CALL BNUMO(RJI,3)
       PLOT2(I,P2DYP1-J)=A(1)
       PLOT2(I+1,P2DYP1-J)=A(2)
       PLOT2(I+2,P2DYP1-J)=A(3)
422    CONTINUE
C-
C-       LEAST SQUARES STRAIGHT LINE APPROXIMATION (LSSLA) FOR CFD
C-
       LS=0
       LS1=0
```

```
      LS2=0
      SX=0.0
      SY=0.0
      SXY=0.0
      SXX=0.0
      SLOPE=0.0
      SEPT=0.0
      DO 430 I=1,ITOT
      YAXIS=(RANK(I)/.90)*54.+6.0
      IY=YAXIS
      IF((YAXIS-IY).GE..5)IY=IY+1
      XAXIS=(FFF(I)/100.)*200.+10.0
      IX=XAXIS
      IF((XAXIS-IX).GE..5)IX=IX+1
      PLOT2(IX,P2DYP1-IY)=SYM
      IF(RANK(I).LT..20)LS1=LS1+1
      IF(RANK(I).GE..20.AND.RANK(I).LE..35)LS=LS+1
      IF(RANK(I).GT..35)LS2=LS2+1
      SX=FFF(I)+SX
      SY=RANK(I)+SY
      SXY=FFF(I)*RANK(I)+SXY
      SXX=FFF(I)*FFF(I)+SXX
430   CONTINUE
      ALS=LS
      ALS1=LS1
      ALS2=LS2
      COUNT=ITOT
      PERC=ALS/COUNT*100.0
      PERC1=ALS1/COUNT*100.0
      PERC2=ALS2/COUNT*100.0
C-
C-      SLOPE OF LSSLA
C-
      SLOPE=(SXY-(SX*SY)/COUNT)/(SXX-(SX*SX)/COUNT)
C-
C-      INTERCEPT OF LSSLA
C-
      SEPT=(SY-SLOPE*SX)/COUNT
      X1=(0.0-SEPT)/SLOPE*2.0+10.0
      Y1=10.0
      IF(X1.LT.10.0.OR.X1.GT.P2DX)X1=10.0
      IF(X1.EQ.10.0)Y1=SEPT/.90*54.0+6.0
      IX1=X1
      IY1=Y1
      IF((X1-IX1).GT..5)IX1=IX1+1
      IF((Y1-IY1).GT..5)IY1=IY1+1
      X2=(.90-SEPT)/SLOPE*2.0+10.0
      Y2=.90
      IF(X2.LT.10.0.OR.X2.GT.P2DX)X2=P2DX
      IF(X2.EQ.P2DX)Y2=(SLOPE*100+SEPT)/.90*54+6.0
      IX2=X2
      IY2=Y2
      IF((X2-IX2).GT..5)IX2=IX2+1
      IF((Y2-IY2).GT..5)IY2=IY2+1
C-
C-      PLACEMENT OF MARKERS FOR END POINTS OF LSSLA--SYM2 (M)
```

```
C-      IS USED IF A DATA POINT IS BEING MARKED OVER & SYM3 (0)
C-      IS USED OTHERWISE
C-
      IF(PLOT2(IX1,P2DYP1-IY1).EQ.SYM)
     - PLOT2(IX1,P2DYP1-IY1)=SYM2
      IF(PLOT2(IX1,P2DYP1-IY1).EQ.COLONS.OR.PLOT2(IX1,P2DYP1-IY1)
     - .EQ.MINUS
     - .OR.PLOT2(IX1,P2DYP1-IY1).EQ.EQ1)
     - PLOT2(IX1,P2DYP1-IY1)=SYM3
      IF(PLOT2(IX2,P2DYP1-IY2).EQ.SYM)
     - PLOT2(IX2,P2DYP1-IY2)=SYM2
      IF(PLOT2(IX2,P2DYP1-IY2).EQ.COLONS.OR.PLOT2(IX2,P2DYP1-IY2)
     - .EQ.MINUS
     - .OR.PLOT2(IX2,P2DYP1-IY2).EQ.EQ1)
     - PLOT2(IX2,P2DYP1-IY2)=SYM3
C-
C-      PRINT OUT OF EQUIPOTENTIAL CURVES, STATISTICAL DATA, AND
C-      FREQUENCY DISTRIBUTION
C-
C-      DESCRIPTIVE INFO AND PLOT SYMBOL VALUE LEGEND FOR
C-      EQUIPOTENTIAL ARRAY
C-
      WRITE(1,901)(INFO(I),I=1,24)
901   FORMAT(' ',14(/' '),10X,24A4,15X,'EQUIPOTENTIAL VALUE ',
     -  'LEGEND')
      WRITE(1,902)(INFO(I),I=25,48),(PLTSYM(J),J=1,10)
902   FORMAT(11X,24A4,15X,'SYMBOL',8X,A1,8X,A1,8X,A1,8X,A1,
     -  8X,A1,8X,A1,8X,A1,8X,A1,8X,A1,8X,A1)
      WRITE(1,903)(INFO(I),I=49,72),(PLTVAL(J),J=1,30)
903   FORMAT(11X,24A4,15X,'VALUE ',6X,3A1,6X,3A1,6X,3A1,6X,
     -  3A1,6X,3A1,6X,3A1,6X,3A1,6X,3A1,6X,3A1,6X,3A1,6X,3A1)
      WRITE(1,904) TDIR,SPAN,DATE
904   FORMAT(1X,/5X,/15X,'EQUIPOTENTIAL CURVES FOR ',3A4,' LANES OF'
     - ,' SPAN  ',I1,40X,'DATA TAKEN  ',A8,/5X)
C-
C-      EQUIPOTENTIAL PLOT WRITTEN OUT AS ARRAY
C-
      WRITE(1,905)PLOT
905   FORMAT(5X,211A1)
      WRITE(1,925)(INFO(I),I=25,48)
925   FORMAT(' ',25(/' '),9X,24A4,10X,'STATISTICAL DATA & HALF '
     -  ,' CELL FREQUENCY DISTRIBUTION ')
      WRITE(1,926) TDIR,SPAN,DATE,ITOT,MEAN,MODE,SD,PERC1,PERC2
926   FORMAT(20X,'STATISTICS FOR ' ,3A4,' LANES OF SPAN ',
     -  I1,40X,'DATA TAKEN ',A8,/25X,'FOR ',I4,' DATA POINTS;  ',
     -  10X,'MEAN = ',F4.2,10X,'MODE=',F4.2,10X,'STANDARD DEVIATION=',
     -  F4.2,/50X,F5.1,'  PERCENT OF DATA POINTS ARE BELOW .20 VOLTS',
     -  10X,F5.1,'  PERCENT OF DATA POINTS ARE ABOVE .35 VOLTS.')
      IF(SMOD(1).LE.0.)GO TO 942
      ISMOD=0
      DO 930 I=1,10
      IF(SMOD(I).LE.0.0)GO TO 940
930   CONTINUE
      IERR(5)=1
940   ISMOD=I-1
      WRITE(1,941)(SMOD(I),I=1,ISMOD)
```

```
941    FORMAT(' ',9X,'MODE ALSO =',F4.2,5X,'  =',F4.2,5X,'  =',F4.2,
     -    5X,'  =',F4.2,5X,'  =',F4.2,5X,'  =',F4.2)
942    WRITE(1,943)
943    FORMAT(20X,/20X,'CUMULATIVE FREQUENCY DISTRIBUTION')
C-
C-       CUMULATIVE FREQUENCY DISTRIBUTION PRINTED OUT AS ARRAY
C-
       WRITE(1,960)PLOT2
960    FORMAT(5X,210A1)
       WRITE(1,970)
970    FORMAT(1X,8(/' '))
       GO TO 2
1000   CLOSE(UNIT=1,STATUS='KEEP')
       STOP
       END
```

```
main  Local Symbols

Name                          Class    Type              Size    Offset

NTCOL . . . . . . . . . . . . local    INTEGER*4            4     000a
TEST. . . . . . . . . . . . . local    REAL*4               4     000e
ITOT. . . . . . . . . . . . . local    INTEGER*4            4     0012
IROW. . . . . . . . . . . . . local    INTEGER*4            4     001e
PLOTR1. . . . . . . . . . . . local    CHAR*1              37     0020
SLOPE . . . . . . . . . . . . local    REAL*4               4     0022
SXX . . . . . . . . . . . . . local    REAL*4               4     0026
ISTAR . . . . . . . . . . . . local    INTEGER*4            4     002a
PERIOD. . . . . . . . . . . . local    REAL*4               4     002e
SXY . . . . . . . . . . . . . local    REAL*4               4     0032
JSTAR . . . . . . . . . . . . local    INTEGER*4            4     0036
PLUS. . . . . . . . . . . . . local    REAL*4               4     003a
GRHVAL. . . . . . . . . . . . local    REAL*4               4     003e
ABC . . . . . . . . . . . . . local    REAL*4               4     0042
FPLOT . . . . . . . . . . . . local    CHAR*1              32     0046
NROW. . . . . . . . . . . . . local    INTEGER*4            4     0046
EQ1 . . . . . . . . . . . . . local    REAL*4               4     004a
X1. . . . . . . . . . . . . . local    REAL*4               4     004e
COUNT . . . . . . . . . . . . local    REAL*4               4     0052
I . . . . . . . . . . . . . . local    INTEGER*4            4     0056
X2. . . . . . . . . . . . . . local    REAL*4               4     005a
Y1. . . . . . . . . . . . . . local    REAL*4               4     005e
J . . . . . . . . . . . . . . local    INTEGER*4            4     0062
FPLOT2. . . . . . . . . . . . local    CHAR*1              26     0066
Y2. . . . . . . . . . . . . . local    REAL*4               4     0066
K . . . . . . . . . . . . . . local    INTEGER*4            4     006a
SROW. . . . . . . . . . . . . local    REAL*4               4     006e
L . . . . . . . . . . . . . . local    INTEGER*4            4     0072
MINUS . . . . . . . . . . . . local    INTEGER*4            4     0076
XAXIS . . . . . . . . . . . . local    REAL*4               4     007a
JSMVAL. . . . . . . . . . . . local    INTEGER*4            4     007e
SPLOT . . . . . . . . . . . . local    CHAR*1              25     0080
YAXIS . . . . . . . . . . . . local    REAL*4               4     0082
TERVAL. . . . . . . . . . . . local    REAL*4               4     0086
COLONS. . . . . . . . . . . . local    REAL*4               4     008a
```

```
main  Local Symbols

Name                          Class    Type              Size    Offset

O . . . . . . . . . . . . . . local    REAL*4               4     008e
LS1 . . . . . . . . . . . . . local    INTEGER*4            4     0092
ALS1. . . . . . . . . . . . . local    REAL*4               4     0096
LS2 . . . . . . . . . . . . . local    INTEGER*4            4     009a
SPLOT2. . . . . . . . . . . . local    CHAR*1              50     009a
HIGH1 . . . . . . . . . . . . local    REAL*4               4     009e
ICOUNS. . . . . . . . . . . . local    INTEGER*4            4     00a2
IX1 . . . . . . . . . . . . . local    INTEGER*4            4     00a6
ALS2. . . . . . . . . . . . . local    REAL*4               4     00aa
II. . . . . . . . . . . . . . local    INTEGER*4            4     00ae
HIGH2 . . . . . . . . . . . . local    REAL*4               4     00b2
FFF . . . . . . . . . . . . . local    REAL*4             800     00b6
IX2 . . . . . . . . . . . . . local    INTEGER*4            4     03d6
IY1 . . . . . . . . . . . . . local    INTEGER*4            4     03da
JI. . . . . . . . . . . . . . local    INTEGER*4            4     03de
PLTVAL. . . . . . . . . . . . local    CHAR*1              30     03e2
IY2 . . . . . . . . . . . . . local    INTEGER*4            4     0400
JK. . . . . . . . . . . . . . local    INTEGER*4            4     0404
ISPLIT. . . . . . . . . . . . local    INTEGER*4            4     0408
IEMI2 . . . . . . . . . . . . local    INTEGER*4            4     040c
ITERVL. . . . . . . . . . . . local    INTEGER*4            4     0410
IN. . . . . . . . . . . . . . local    INTEGER*4            4     0414
IEMJ2 . . . . . . . . . . . . local    INTEGER*4            4     0418
SD. . . . . . . . . . . . . . local    REAL*4               4     041c
TERPRM. . . . . . . . . . . . local    REAL*4               4     0420
INC . . . . . . . . . . . . . local    INTEGER*4            4     0424
INTVAX. . . . . . . . . . . . local    INTEGER*4            4     0428
PERC1 . . . . . . . . . . . . local    REAL*4               4     042c
IEM . . . . . . . . . . . . . local    INTEGER*4            4     0430
INTVAY. . . . . . . . . . . . local    INTEGER*4            4     0434
BLANK3. . . . . . . . . . . . local    REAL*4               4     0438
PERC2 . . . . . . . . . . . . local    REAL*4               4     043c
JEM . . . . . . . . . . . . . local    INTEGER*4            4     0440
PLOTMP. . . . . . . . . . . . local    REAL*4               4     0444
BETA. . . . . . . . . . . . . local    REAL*4             924     0448
P1DX. . . . . . . . . . . . . local    REAL*4               4     07e4
COL . . . . . . . . . . . . . local    REAL*4               4     07e8
P2DX. . . . . . . . . . . . . local    REAL*4               4     07ec
P1DY. . . . . . . . . . . . . local    REAL*4               4     07f0
DATE. . . . . . . . . . . . . local    CHAR*8               8     07f4
LS. . . . . . . . . . . . . . local    INTEGER*4            4     07fc
P2DY. . . . . . . . . . . . . local    REAL*4               4     0800
P1DYP1. . . . . . . . . . . . local    REAL*4               4     0804
ALS . . . . . . . . . . . . . local    REAL*4               4     0808
HIGH. . . . . . . . . . . . . local    REAL*4               4     080c
P2DYP1. . . . . . . . . . . . local    REAL*4               4     0810
LOGIC2. . . . . . . . . . . . local    LOGICAL*4            4     0814
MOD . . . . . . . . . . . . . local    REAL*4            1600     0818
IX. . . . . . . . . . . . . . local    INTEGER*4            4     0e58
MEAN. . . . . . . . . . . . . local    REAL*4               4     0e5c
IY. . . . . . . . . . . . . . local    INTEGER*4            4     0e60
```

```
                                                       PAGE  17
                                                       09-15-91
                                                       20:46:34

                              Microsoft FORTRAN Optimizing Compiler Version 4.00


main  Local Symbols

Name                      Class   Type                Size   Offset

IDIFF . . . . . . . . . . local   INTEGER*4              4    0e64
LOW1. . . . . . . . . . . local   REAL*4                 4    0e68
IEMI. . . . . . . . . . . local   INTEGER*4              4    0e6c
LOW2. . . . . . . . . . . local   REAL*4                 4    0e70
RJI . . . . . . . . . . . local   REAL*4                 4    0e74
IEMJ. . . . . . . . . . . local   INTEGER*4              4    0e78
MODE. . . . . . . . . . . local   REAL*4                 4    0e7c
ALPHA . . . . . . . . . . local   REAL*4              2772    0e80
ICOL. . . . . . . . . . . local   INTEGER*4              4    1954
TEMP1 . . . . . . . . . . local   REAL*4                 4    1958
SUM2. . . . . . . . . . . local   REAL*4                 4    195c
IDXNC2. . . . . . . . . . local   INTEGER*4              4    1960
DXINC2. . . . . . . . . . local   REAL*4                 4    1964
BLANK . . . . . . . . . . local   REAL*4                 4    1968
IDYNC2. . . . . . . . . . local   INTEGER*4              4    196c
DYINC2. . . . . . . . . . local   REAL*4                 4    1970
PLTSYM. . . . . . . . . . local   CHAR*1                10    1974
PERC. . . . . . . . . . . local   REAL*4                 4    197e
ISAVE2. . . . . . . . . . local   INTEGER*4              4    1982
SX. . . . . . . . . . . . local   REAL*4                 4    1986
TER . . . . . . . . . . . local   REAL*4                 4    198a
SYM2. . . . . . . . . . . local   REAL*4                 4    198e
EQU . . . . . . . . . . . local   REAL*4                16    1992
SY. . . . . . . . . . . . local   REAL*4                 4    19a2
NCOL. . . . . . . . . . . local   INTEGER*4              4    19a6
SYM3. . . . . . . . . . . local   REAL*4                 4    19aa
INFO. . . . . . . . . . . local   CHAR*4               288    19ae
RANK. . . . . . . . . . . local   REAL*4               800    1ace
LOGIC . . . . . . . . . . local   LOGICAL*4              4    1dee
SAVE. . . . . . . . . . . local   REAL*4                 4    1df2
ILABX . . . . . . . . . . local   INTEGER*4              4    1df6
TEST1 . . . . . . . . . . local   REAL*4                 4    1dfa
ILABY . . . . . . . . . . local   INTEGER*4              4    1dfe
SCOL. . . . . . . . . . . local   REAL*4                 4    1e02
PLOT2 . . . . . . . . . . local   CHAR*1             12600    1e06
XINC. . . . . . . . . . . local   REAL*4                 4    4f3e
IXNC. . . . . . . . . . . local   INTEGER*4              4    4f42
TEST2 . . . . . . . . . . local   REAL*4                 4    4f46
SPAN. . . . . . . . . . . local   INTEGER*4              4    4f4a
LOW . . . . . . . . . . . local   REAL*4                 4    4f4e
IERR. . . . . . . . . . . local   INTEGER*4             20    4f52
IYNC. . . . . . . . . . . local   INTEGER*4              4    4f66
YINC. . . . . . . . . . . local   REAL*4                 4    4f6a
TEST3 . . . . . . . . . . local   REAL*4                 4    4f6e
MODEN . . . . . . . . . . local   INTEGER*4              4    4f72
TDIR. . . . . . . . . . . local   CHAR*8                24    4f76
SMOD. . . . . . . . . . . local   REAL*4                80    4f8e
TEST4 . . . . . . . . . . local   REAL*4                 4    4fde
ISTAR2. . . . . . . . . . local   INTEGER*4              4    4fe2
TEST5 . . . . . . . . . . local   REAL*4                 4    4fe6
SUM . . . . . . . . . . . local   REAL*4                 4    4fea
```

```
                                  Microsoft FORTRAN Optimizing Compiler Version 4.00


main  Local Symbols

Name                          Class   Type              Size   Offset

DXINC . . . . . . . . . . . . local   REAL*4               4    4fee
IDXNC . . . . . . . . . . . . local   INTEGER*4            4    4ff2
JSTAR2. . . . . . . . . . . . local   INTEGER*4            4    4ff6
TEMP. . . . . . . . . . . . . local   REAL*4               4    4ffa
DYINC . . . . . . . . . . . . local   REAL*4               4    4ffe
IDYNC . . . . . . . . . . . . local   INTEGER*4            4    5002
TOT . . . . . . . . . . . . . local   REAL*4               4    5006
ISAVE . . . . . . . . . . . . local   INTEGER*4            4    500a
ROW . . . . . . . . . . . . . local   REAL*4               4    500e
LABELX. . . . . . . . . . . . local   REAL*4             252    5012
SYM . . . . . . . . . . . . . local   REAL*4               4    510e
LABELY. . . . . . . . . . . . local   REAL*4             132    5112
I2. . . . . . . . . . . . . . local   INTEGER*4            4    5196
ISMOD . . . . . . . . . . . . local   INTEGER*4            4    519a
SEPT. . . . . . . . . . . . . local   REAL*4               4    519e
K1. . . . . . . . . . . . . . local   INTEGER*4            4    51a2
IOPT. . . . . . . . . . . . . local   INTEGER*4           20    51a6
K2. . . . . . . . . . . . . . local   INTEGER*4            4    51ba
L2. . . . . . . . . . . . . . local   INTEGER*4            4    51be
PLOT. . . . . . . . . . . . . local   CHAR*1           11605    51c2
PLOTR2. . . . . . . . . . . . EQUDAT  REAL*4             148    0010
A . . . . . . . . . . . . . . EQUDAT                       5    0000
ANUMO . . . . . . . . . . . . EQUDAT                      10    0005

     742           SUBROUTINE HIGHLO(HIGH1,LOW1,A1,B,TER,LOGIC,INC)
     743           LOGICAL LOGIC
     744           REAL LOW1
     745           DIMENSION PLOTR2(37)
     746           CHARACTER A(5)*1,ANUMO(10)*1
     747           COMMON /EQUDAT/ A,ANUMO,PLOTR2
     748     C-
     749     C-      PICK HIGH & LOW VALUES OF TWO GRID VALUES CURRENTLY BEING
     750     C-            EXAMINED
     751     C-      SET LOGIC FALSE IF CURRENT PLOTER (INTERVAL) VALUE IS NOT
     752     C-            BETWEEN HIGH & LOW VALUES
     753     C-            OR IF A & B ARE IDENTICAL
     754     C-            OR IF PLOTER INTERVAL VALUE IS IDENTICAL TO EITHER
     755     C-                  A OR B
     756     C-
     757           IF(A1.LT.B)LOW1=A1
     758           IF(A1.GE.B)HIGH1=A1
     759           IF(B.LE.A1)LOW1=B
     760           IF(B.GT.A1)HIGH1=B
     761           TER=HIGH1-LOW1
     762           LOGIC=PLOTR2(INC).LT.LOW1.OR.PLOTR2(INC).GT.HIGH1.OR.TER
     763          - .EQ..0.OR.PLOTR2(INC).EQ.A1.OR.PLOTR2(INC).EQ.B
     764           RETURN
     765           END
```

```
HIGHLO  Local Symbols

Name                       Class    Type              Size    Offset

INC . . . . . . . . . . . . param                              0006
LOGIC . . . . . . . . . . . param                              000a
TER . . . . . . . . . . . . param                              000e
B . . . . . . . . . . . . . param                              0012
A1. . . . . . . . . . . . . param                              0016
LOW1. . . . . . . . . . . . param                              001a
HIGH1 . . . . . . . . . . . param                              001e
PLOTR2. . . . . . . . . . . EQUDAT   REAL*4            148     0010
A . . . . . . . . . . . . . EQUDAT                       5     0000
ANUMO . . . . . . . . . . . EQUDAT                      10     0005
```

```
            SUBROUTINE BNUMO(RNUM,N)
      C-
      C-     THIS SUBROUTINE CONVERTS A REAL NUMBER TO AN ALPHANUMERIC
      C-          REPRESENTATION --UP TO FIVE SIGNIFICANT DIGITS
      C-          INCLUDING DECIMAL POINT ARE ALLOWED
      C-
      C-          RNUM--NUMBER TO BE CONVERTED
      C-          A(5)--ARRAY FOR STORING ALPHANUMERIC REPRESENTATION
      C-          OF RNUM
      C-          N--NUMBER OF SIGNIFICANT DIGITS INCLUDING DECIMAL
      C-          POINT
      C-
            DIMENSION PLOTR2(37)
            CHARACTER A(5)*1,ANUMO(10)*1
            COMMON /EQUDAT/ A,ANUMO,PLOTR2
      C-
      C-     DETERMINE IF NUMBER IS GREATER THAN OR LESS THAN 1.00
      C-
            K=1
            I=1
            IPERIOD=0
            TNUM=RNUM
            IF(TNUM.LT.1.00)GO TO 200
      C-
      C-     NUMBER IS GREATER THAN 1.00
      C-
      100   IF(I.GT.N)GO TO 10
      101   TNUM=TNUM/10
            K=K+1
            IF(TNUM.GE.10.0)GO TO 101
            GO TO 220
      C-
      C-         NUMBER LESS THAN 1.00
      C-
      200   A(I)='.'
            I=I+1
            IPERIOD=1
      210   IF(I.EQ.K+1.AND.IPERIOD.EQ.0)THEN
            A(I)='.'
            IPERIOD=1
            I=I+1
```

```
  Line#  Source Line        Microsoft FORTRAN Optimizing Compiler Version 4.00

    807         ENDIF
    808         IF(I.GT.N)GO TO 10
    809         IF(TNUM.LT.1.00)TNUM=TNUM*10.0
    810   220   CALL AMATCH(TNUM,I)
    811         I=I+1
    812         GO TO 210
    813   10    CONTINUE
    814         RETURN
    815         END


BNUMO  Local Symbols

Name                         Class    Type              Size    Offset

N . . . . . . . . . . . . . .param                              0006
RNUM. . . . . . . . . . . . .param                              000a
TNUM. . . . . . . . . . . . .local    REAL*4               4    7f18
IPERIO. . . . . . . . . . . .local    INTEGER*4            4    7f1c
I . . . . . . . . . . . . . .local    INTEGER*4            4    7f20
K . . . . . . . . . . . . . .local    INTEGER*4            4    7f24
PLOTR2. . . . . . . . . . . .EQUDAT   REAL*4             148    0010
A . . . . . . . . . . . . . .EQUDAT                        5    0000
ANUMO . . . . . . . . . . . .EQUDAT                       10    0005

    816         SUBROUTINE AMATCH(RNUM,K)
    817   C-
    818   C-         THIS SUBROUTINE MATCHES A NUMBER BETWEEN 0 AND 9 WITH ITS
    819   C-         ALPHANUMERIC EQUIVALENT
    820   C-
    821         DIMENSION PLOTR2(37)
    822         CHARACTER A(5)*1,ANUMO(10)*1
    823         COMMON /EQUDAT/ A,ANUMO,PLOTR2
    824         NUM=RNUM + .005
    825         DO 100 I=1,9
    826         IF(NUM.EQ.I)A(K)=ANUMO(I)
    827   100   CONTINUE
    828         RNUM=RNUM-NUM
    829         IF(NUM.EQ.0)A(K)=ANUMO(10)
    830         RETURN
    831         END


AMATCH  Local Symbols

Name                         Class    Type              Size    Offset

K . . . . . . . . . . . . . .param                              0006
RNUM. . . . . . . . . . . . .param                              000a
I . . . . . . . . . . . . . .local    INTEGER*4            4    7f28
NUM . . . . . . . . . . . . .local    INTEGER*4            4    7f2c
PLOTR2. . . . . . . . . . . .EQUDAT   REAL*4             148    0010
A . . . . . . . . . . . . . .EQUDAT                        5    0000
ANUMO . . . . . . . . . . . .EQUDAT                       10    0005

    832         BLOCK DATA EQUCOM
```

```
                                                                          PAGE  21
                                                                          09-15-91
                                                                          20:46:34

  Line#  Source Line          Microsoft FORTRAN Optimizing Compiler Version 4.00

    833        DIMENSION PLOTR2(37)
    834        CHARACTER A(5)*1,ANUMO(10)*1
    835        COMMON /EQUDAT/ A,ANUMO,PLOTR2
    836        DATA ANUMO/'1','2','3','4','5','6','7','8','9','0'/
    837        DATA PLOTR2/0.000,0.025,0.050,0.075,0.100,0.125,0.150,
    838       -0.175,0.200,0.225,0.250,0.275,0.300,0.325,0.350,0.375,
    839       -0.400,0.425,0.450,0.475,0.500,0.525,0.550,0.575,0.600,
    840       -0.625,0.650,0.675,0.700,0.725,0.750,0.775,0.800,0.825,
    841       -0.850,0.875,0.900/
    842        END

(null)  Local Symbols

Name                          Class    Type              Size    Offset

PLOTR2. . . . . . . . . . . . EQUDAT   REAL*4             148     0010
A . . . . . . . . . . . . . . EQUDAT                        5     0000
ANUMO . . . . . . . . . . . . EQUDAT                       10     0005


Global Symbols

Name                          Class    Type              Size    Offset

AMATCH. . . . . . . . . . . . FSUBRT   ***                ***     4c10
BNUMO . . . . . . . . . . . . FSUBRT   ***                ***     4a55
EQUDAT. . . . . . . . . . . . common   CHAR*164           164     0000
HIGHLO. . . . . . . . . . . . FSUBRT   ***                ***     4870
main. . . . . . . . . . . . . FSUBRT   ***                ***     0000

Code size = 4870 (18544)
Data size = 0282 (642)
Bss size  = 7f30 (32560)

No errors detected
```

Variable Definition Table

Variable Name	Purpose
A(5)	Holds alphanumeric representation of a real number of up to 5 significant digits.
ALPHA(33,21)	Holds half cell potential grid values as alphanumeric symbols for use in graph print out.
ANUMO(10)	Holds alphanumeric representation of numbers 0 - 9.
BETA(5,25)	Holds half cell potential grid values as real numbers for calculations.
COL	Number of one character spaces between data elements on abscissa.
DATE	Date of half cell readings
EQU(4)	Holds four adjacent half cell potential values (grid corner values) for intermediate analysis of the area within the grid.
FFF(200)	Frequency Distribution--Abscissa Co-ordinate values.
FPLOT(32)	Frequency Distribution--Ordinate Label.
FPLOT2(26)	Frequency Distribution--Abscissa Label.
GRHVAL	Minimum number of equipotential plot intervals--Interval value is shifted (i.e. 0.025, 0.050, or 0.100 volts) to allow GRHVAL number of contours if possible--Graph will be printed as long as at least two contours are created.
ICOUNS	Total number of grid data points. Equals the number of rows times the number of columns.
ICOL	Number of one character spaces between data elements on ordinate.
IDEBUG	0--No debugging printout. 1--Debugging printout.
INFO	Alphanumeric descriptive information on test site.
IGRID	0--Print Grid. 1--Don't Print Grid. NOT IMPLEMENTED
IGRIDV	0--Write half cell potential values on grid matrix. 1--Don't Write. NOT IMPLEMENTED
IGRAPH	0--Print both graphs. 1--Print only half cell contours. 2--Print only cumulative frequency results. NOT IMPLEMENTED
IROW	Number of one character spaces between data elements on abscissa.
ISAVE	Pointer to lowest contour value in current grid cell.
ISAVE2	Pointer to highest contour value in current grid cell.
ISTAT	0--All statistics in output. 1--No statistics in output.
ISPLIT	0--Normal graph printout. 1--Split graph.
ITERVAL	Number of 0.025 volt spacings in plot contour interval.
ITOT	NROW times NCOL.
ISYM	0--Symbol used in place of actual contour value. 1--Actual contour values placed on graph. NOT IMPLEMENTED.
LABELX(63)	Numerical spacing labels for abscissa.

Variable Definition Table (continued)

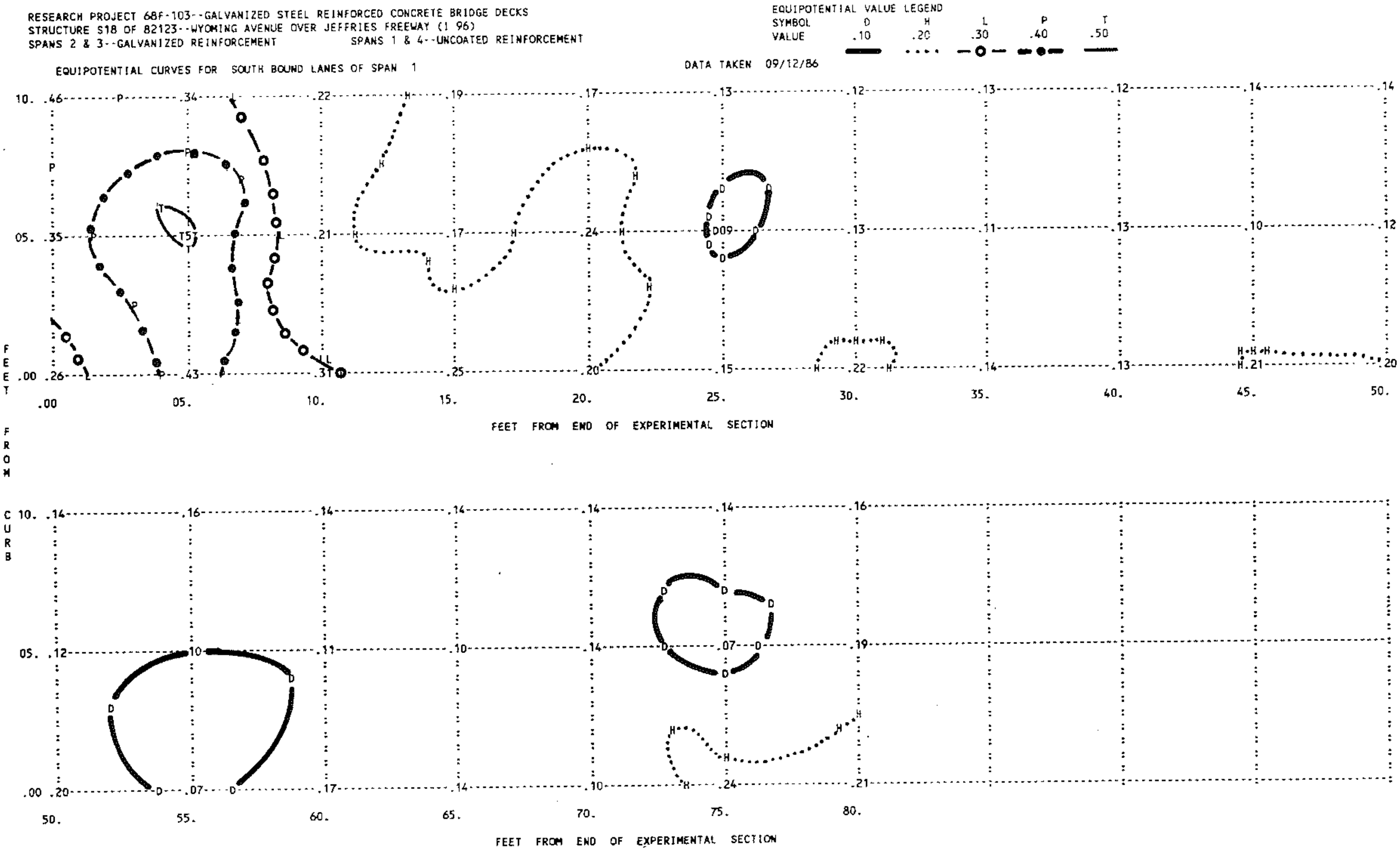
Variable Name	Purpose
LABELY(33)	Numerical spacing labels for ordinate.
LOGIC	When true, plot symbol is not placed--Plot interval is out of range.
LOGIC2	See LOGIC.
LOW	Lowest value of EQU(1) - EQU(4), the grid cell corner values.
LPLOT(30)	Least squares straight line--label.
LPLOT2(30)	Least squares straight line--equation.
MEAN	Arithmetic mean of all half cell potentials for a given experimental grid.
MOD(200,2)	MOD(I,J)--Half cell potential values (I) and their frequency of occurrence (j) for a given experimental site.
MODE	Mode of all half cell potentials for a given experimental grid.
PLOT(191,55)	Half cell potential contour graph.
PLOT2(210,60)	Cumulative frequency distribution graph.
PLOTR1(37)	Plot contour interval value.
PLOTR2(37)	Plot symbol corresponding to PLOTR1(I) value.
PLTSYM(10)	Symbol representing contour value that is actually placed on graph.
PLTVAL(30)	Alphanumeric representation of value corresponding to PLTSYM.
ROW	Number of one character spaces between data elements on ordinate.
TDIR	Traffic direction of experimental site.
TEMP	Ambient temperature in degrees ^{o}F. If TEMP is outside of plus or minus 10 degrees from 72 ^{o}f and within the range 32 - 120 ^{o}F, supplying a number for TEMP in the input data file will result in temperature correction of half cell potential values.
TERVAL	Number of 0.025 volt spacings in plot contour interval.
TEST	Range of half cell potential values (HIGH - LOW) for an experimental grid.
SCOL	Default value for COL (i.e., 20).
SD	Standard Deviation of half cell potential values for a given experimental grid.
SLOPE	Slope of least squares straight line for the cumulative frequency data.
SMOD(20)	Stores multiple mode values, if necessary.
SPAN	Bridge span number of experimental site.
SROW	Default value for ROW (i.e., 10).

Sample Computer Input--

```
RESEARCH PROJECT 68F-103--GALVANIZED STEEL REINFORCED CONCRETE BRIDGE DE
CKS                       STRUCTURE S18 OF 82123--WYOMING AVENUE OVER JEFF
RIES FREEWAY (I 96)                                 SPANS 2 & 3--GALVANIZED
REINFORCEMENT             SPANS 1 & 4--UNCOATED REINFORCEMENT
1 SOUTH BOUND09/12/8617 3
.26.35.46
.43.51.34
.31.21.22
.25.17.19
.20.24.17
.15.09.13
.22.13.12
.14.11.13
.13.13.12
.21.10.14
.20.12.14
.07.10.16
.17.11.14
.14.10.14
.10.14.14
.24.07.14
.21.19.16
^Z
```

```
RESEARCH PROJECT 73F-131--EPOXY RESIN COATED REINFORCED CONCRETE BRIDGE
DECKS                     STRUCTURE S13 OF 81103--CURTIS ROAD OVER I 75 EA
ST OF ANN ARBOR                                     SPAN 1--UNCOATED REINFOR
CEMENT                    SPAN 4--GALVANIZED REINFORCEMENT
1 SOUTH BOUND10/24/8410 5
.32.34.31.31.28
.19.25.24.25.22
.20.27.19.24.18
.28.30.24.23.19
.22.26.24.23.22
.24.42.29.21.22
.24.28.25.24.21
.23.35.25.22.20
.24.40.01.13.22
.29.38.09.15.19
^Z
```

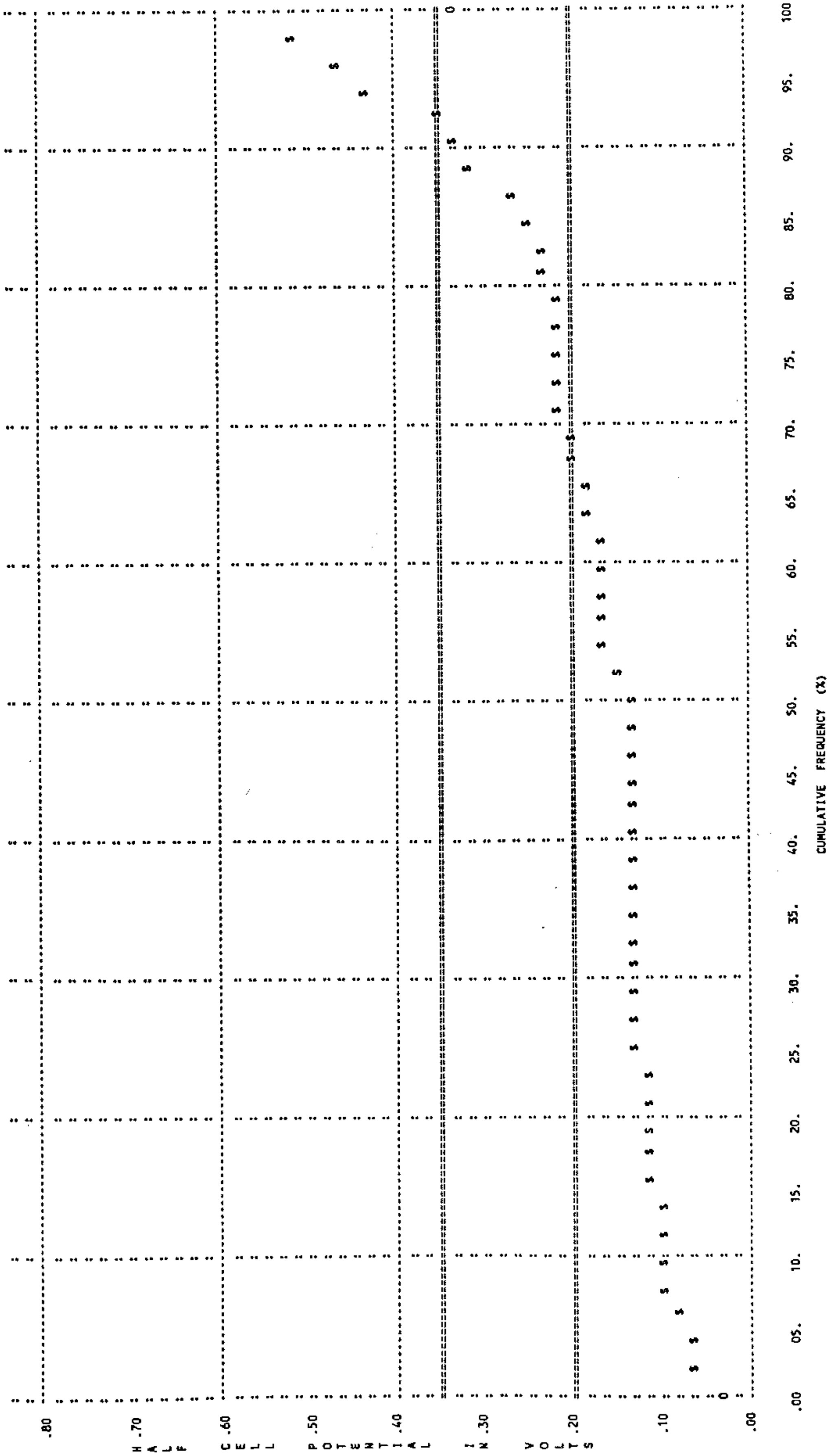
Sample Computer Output (Page 1)



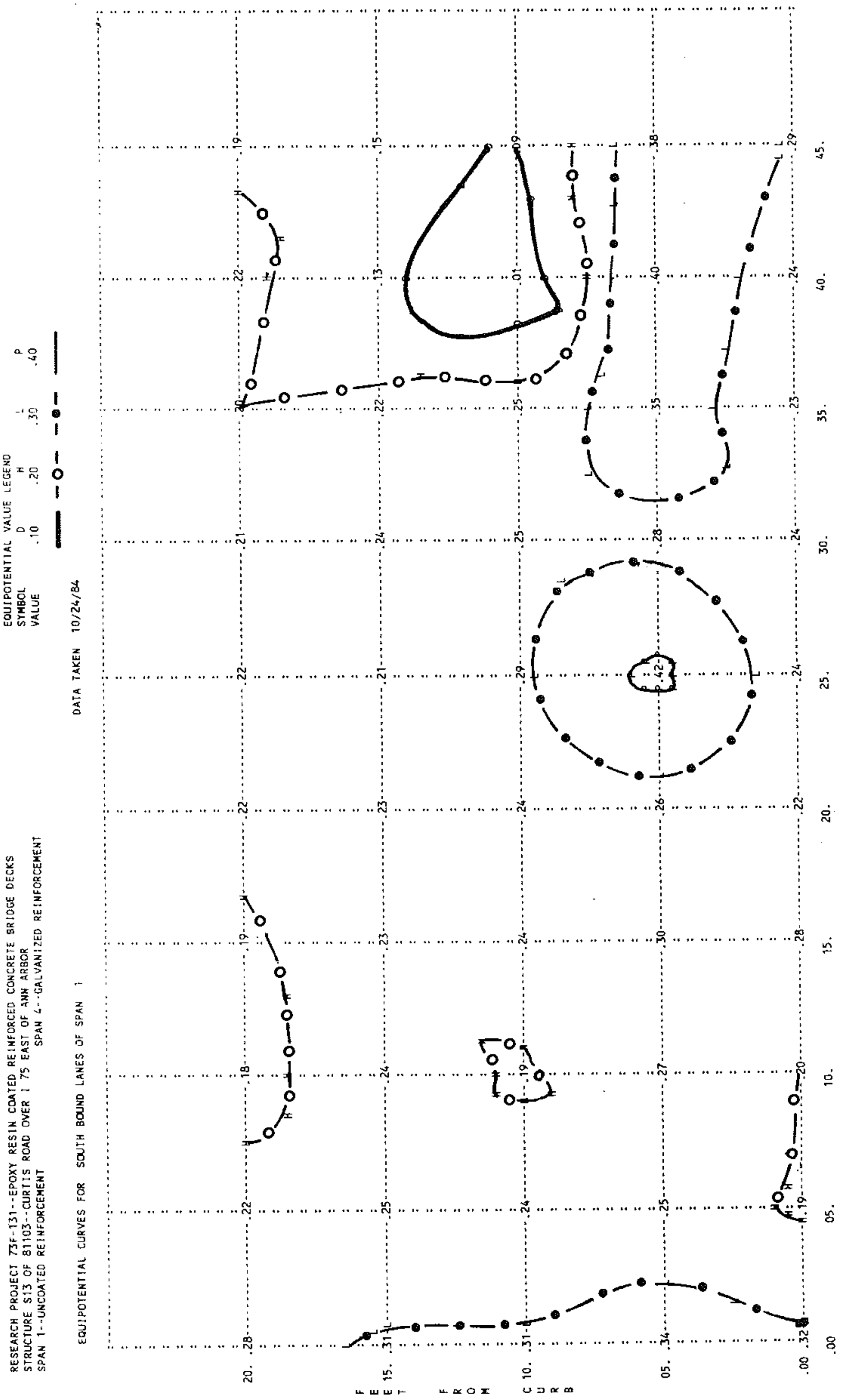
```
RESEARCH PROJECT 68F-103--GALVANIZED STEEL REINFORCED CONCRETE BRIDGE DECKS
STRUCTURE S18 OF 82123--WYOMING AVENUE OVER JEFFRIES FREEWAY (1 96)
SPANS 2 & 3--GALVANIZED REINFORCEMENT          SPANS 1 & 4--UNCOATED REINFORCEMENT

   EQUIPOTENTIAL CURVES FOR  SOUTH BOUND LANES OF SPAN  1

EQUIPOTENTIAL VALUE LEGEND
SYMBOL       D      H      L      P      T
VALUE       .10    .20    .30    .40    .50

DATA TAKEN  09/12/86
```

Sample Computer Output (Page 2)

```
STRUCTURE S18 OF 82123--WYOMING AVENUE OVER JEFFRIES FREEWAY (I 96)          STATISTICAL DATA & HALF  CELL FREQUENCY DISTRIBUTION
       STATISTICS FOR  SOUTH BOUND LANES OF SPAN 1                         DATA TAKEN 09/12/86
          FOR   51 DATA POINTS;        MEAN =  .18       MODE= .14     STANDARD DEVIATION= .10
                        66.7  PERCENT OF DATA POINTS ARE BELOW .20 VOLTS           5.9  PERCENT OF DATA POINTS ARE ABOVE .35 VOLTS.

     CUMULATIVE FREQUENCY DISTRIBUTION
```

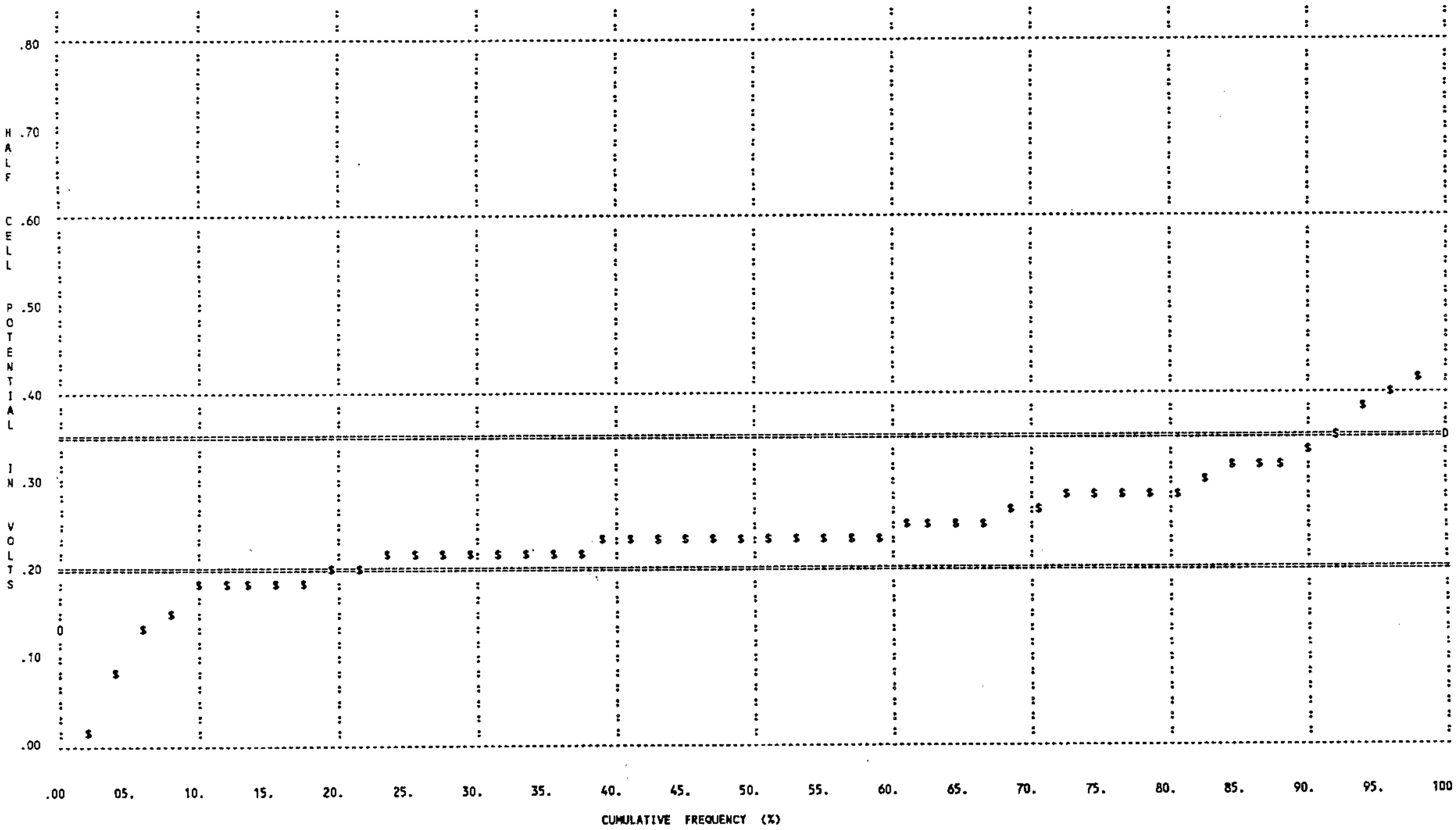


Sample Computer Output (Page 3)



Sample Computer Output (Page 4)

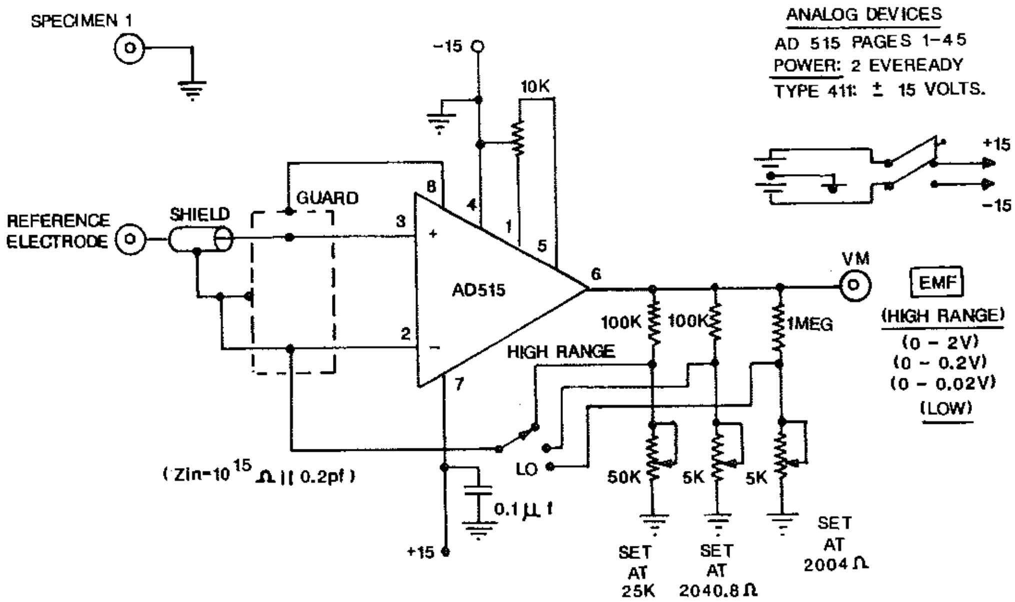
```
:TRUCTURE S13 OF 81103--CURTIS ROAD OVER I 75 EAST OF ANN ARBOR                         STATISTICAL DATA & HALF  CELL FREQUENCY DISTRIBUTION
        STATISTICS FOR  SOUTH BOUND LANES OF SPAN 1                              DATA TAKEN 10/24/84
            FOR   50 DATA POINTS;           MEAN =  .24         MODE= .24         STANDARD DEVIATION= .07
                                    18.0  PERCENT OF DATA POINTS ARE BELOW .20 VOLTS            6.0  PERCENT OF DATA POINTS ARE ABOVE .35 VOLTS.

        CUMULATIVE FREQUENCY DISTRIBUTION
```

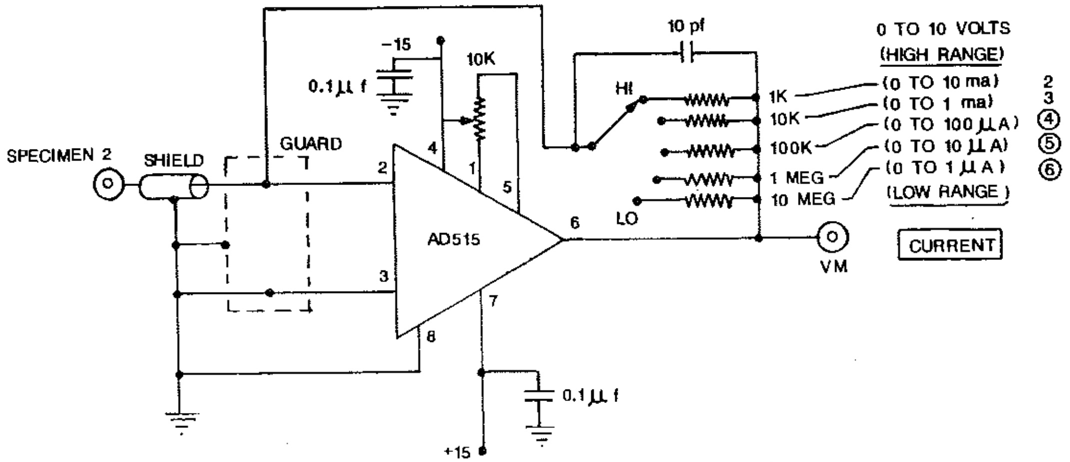


Appendix B

Appendix B Circuit Drawings for Zero Resistance Ammeter

This is the device used for making current measurements between the top and bottom reinforcement mats. This is a minor modification (amplifiers originally used were no longer available requiring substitution) and enhancement of a device proposed by Lauer and Mansfeld for performing zero resistance current measurements.



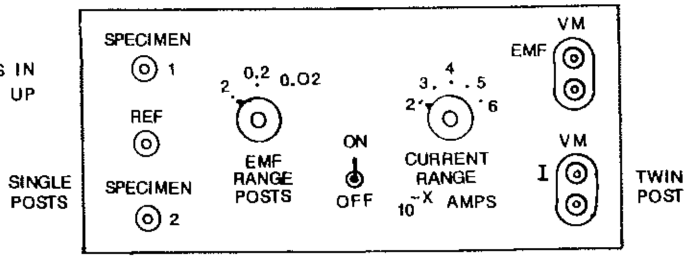


NOTE:

APPLY ALL TECHNIQUES DESCRIBED ON PAGES 1-47 AND 1-48 OF THE ANALOG DEVICES CATALOG. NEGLECT THE SECTION ON INPUT PROTECTION. USE BUD BOX TC-300. PUT BATTERIES IN COMPARTMENT AND LET PANEL SWING UP FOR STORAGE.

EXAMPLE PANEL

ZERO IMPEDANCE AMMETER



Appendix C

GALVANIZING THICKNESSES 68F-103

BLOCK	BAR NUMBER			THICKNESS			
NO.	1	2	3	1	2	3	AVERAGE
1	39	44	46	3.83	3.83	4.83	4.16
2	45	34	41	4.33	4.16	3.83	4.10
3		6	18		1.00	4.66	2.83
4	9	5	31	3.66	3.50	3.00	3.38
5	36	11	25	5.00	3.75	4.00	4.25
6	16	15	21	3.00	5.30	5.16	3.82
7	26	30	8	4.33	4.33	8.83	5.83
8	32	13	16	2.66	4.50	3.75	3.63
9	2	5	33	6.25	5.00	4.75	5.33
10	24	47	33	5.50	5.66	5.00	5.38
11	4	22	7	2.75	4.00	6.25	4.33
12	14	45	8	3.83	4.33	8.83	5.66
13	37	43	25	6.16	5.00	3.83	4.99
14	13	2	29	3.50	5.16	4.66	4.44
15	27	11	7	4.16	4.33	3.66	4.05
16	47	23	20	5.66	3.66	5.00	4.77
17	28	32	35	3.00	4.16	4.50	3.88
18	1	38	40	5.00	3.16	4.16	4.10
19	4	36	12	4.33	5.00	4.33	4.55
20	6	35	3	2.66	3.33	4.75	3.58
21	19	31	12	2.50	3.75	4.75	3.66
22	19	10	42	5.83	4.50	4.66	4.99
30	9			6.00			6.00
31	14	3	18	5.00	4.66	3.00	4.20
32	15		17	4.75		5.83	5.29
33			20			4.33	4.33
34	12	7	1	4.16	5.00	4.50	4.55
35		19			4.00		4.00
36	6	8	21	5.66	4.66	3.75	4.69

Appendix D

'SPALL' INFORMATION FOR GALVANIZED FIELD EXPOSURE SPECIMENS

BLOCK NO.	DATE	BAR NO.	UNCOATED					GALVANIZED					COMMENTS
			CRACKS HAIRLINE (LIN IN)	CRACKS OPEN (LIN IN)	CRACKS TOTAL (LIN IN)	SPALLS (SQ IN)	HOLLOW AREA (SQ IN)	CRACKS HAIRLINE (LIN IN)	CRACKS OPEN (LIN IN)	CRACKS TOTAL (LIN IN)	SPALLS (SQ IN)	HOLLOW AREA (SQ IN)	
1	09-09-74				9								
	09-27-78				15	5							
	11-19-79				9								
	07-14-80	1			12	3							
	06-15-81				9								
	09-12-84				60	18							
2	09-27-78												HEAVY PITTING OVER ENTIRE BLOCK
3	08-16-73												.5" COVER, SOME CRACKS OVER PLAIN BARS, 9 SMALL RUST SPOTS ON PLAIN, 1 SMALL RUST SPOT ON GALVANIZED
	09-11-73				67								3.75 SQ. IN. RUST SPOT ON PLAIN, 0.25 SQ. IN. ON GALVANIZED
	09-09-74		60	6	66								6 SQ. IN. RUST SPOT ON PLAIN
	10-31-75				15								
	05-04-76				15	5							
	08-23-76				18	12							
	09-15-76				48	15							
	09-27-78		20	25	45	68		22		22			PLAIN AREA SPALLED DOWN TO BARS
	11-19-79				48					2			
	07-14-80	1				36							
		2			36	2							
		3			12	12							
		TOTAL			48	14							
	06-05-81	1			36								
		2			3								
		3			15								
		TOTAL			54								
		5								1			
	06-15-81				48					2			
	09-12-84												ABANDONED
4	09-09-74							36		36			
5	08-16-73				11								0.5 INCH WITH SPLICE, FINE CRACKS OVER GALVANIZED, NO RUST
	09-11-73				90					90			7.5 SQ. IN. RUST SPOT ON PLAIN
	09-09-74		72	18	90			75		75			12.D SQ. IN. RUST SPOT ON PLAIN
	10-31-75				32					26		1	
	05-04-76				32	15				26	4	1	
	08-23-76				36					7			
	09-15-76				99	25				30	6		HOLLOW AREA NOW SOLID BY CORING
	09-27-78		5	50	55	100	1						SOME PITTING ON SURFACE
	11-19-79				82					28			
	07-14-80	1			6	30							

'SPALL' INFORMATION FOR GALVANIZED FIELD EXPOSURE SPECIMENS

BLOCK NO.	DATE	BAR NO.	UNCOATED CRACKS HAIRLINE (LIN IN)	UNCOATED CRACKS OPEN (LIN IN)	UNCOATED CRACKS TOTAL (LIN IN)	UNCOATED SPALLS (SQ IN)	UNCOATED HOLLOW AREA (SQ IN)	GALVANIZED CRACKS HAIRLINE (LIN IN)	GALVANIZED CRACKS OPEN (LIN IN)	GALVANIZED CRACKS TOTAL (LIN IN)	GALVANIZED SPALLS (SQ IN)	GALVANIZED HOLLOW AREA (SQ IN)	COMMENTS
		2			24	10							
		3			23	11							
		TOTAL			53	51							
		4									3		
		5									5		
		6								7	16		
		TOTAL								7	24		
	06-05-81	1			33								
		2			16								
		3			21								
		TOTAL			70								
		4								3			
		5								5			
		6								20			
		TOTAL								28			
	06-15-81				82					28			
	09-12-84												ABANDONED
6	09-11-73				10					24			
	09-09-74		15	15	30								
	10-31-75												MANY SMALL SPALLS WITH STONE BELOW
	05-04-76												MANY SMALL SPALLS WITH STONE BELOW
	09-15-76				12								
	09-27-78		30	6	36								SOME PITTING
	09-12-84				108	12	81			108			
7	09-11-73				6					21			
	09-09-74				48					56			
	10-31-75									13			MANY SMALL SPALLS WITH STONE BELOW
	05-04-76				13								SEVERAL SMALL POP OUTS NOT ON BARS
	09-27-78												SURFACE PITTING
	09-12-84				72					84			
8	08-16-73		1		1			1		1			ONE SMALL RUST SPOT ON PLAIN
	09-11-73				7					28			0.25 SQ. IN. RUST SPOT ON PLAIN
	09-09-74		56	6	62			12	24	36			0.5 SQ. IN. RUST SPOT ON PLAIN
	10-31-75									28			
	05-04-76									28			
	08-23-76				9					10			
	09-15-76				12					16			
	09-27-78		20	8	28				16	16			SURFACE PITTING
	11-19-79				14								
	07-14-80	1			24								
		6								12			
	06-15-81				14								

'SPALL' INFORMATION FOR GALVANIZED FIELD EXPOSURE SPECIMENS

BLOCK NO.	DATE	BAR NO.	UNCOATED CRACKS HAIRLINE (LIN IN)	UNCOATED CRACKS OPEN (LIN IN)	UNCOATED CRACKS TOTAL (LIN IN)	UNCOATED SPALLS (SQ IN)	UNCOATED HOLLOW AREA (SQ IN)	GALVANIZED CRACKS HAIRLINE (LIN IN)	GALVANIZED CRACKS OPEN (LIN IN)	GALVANIZED CRACKS TOTAL (LIN IN)	GALVANIZED SPALLS (SQ IN)	GALVANIZED HOLLOW AREA (SQ IN)	COMMENTS
	09-12-84				12					16			
9	08-16-73							1		1			NO RUST
	09-11-73				10					22			
	09-09-74				24			20	20	40			MOST CRACKS IN CORNER
	10-31-75				36								
	05-04-76				36	7					2		
	09-15-76									16			
	09-27-78		29	4	33			14	16	30	3		
	07-14-80					2							
	09-12-84									16			
10	08-16-73												FINE CRACKS OVER 2 PLAIN, 1 GALV. 4 SMALL RUST SPOTS ON PLAIN
	09-11-73				64					61			3.25 SQ. IN. RUST SPOT ON PLAIN
	09-09-74		75	15	90					90			16.0 SQ. IN. RUST SPOT ON PLAIN
	10-31-75				15					5			
	05-04-76				15	12				5	3		
	08-23-76				52								
	09-15-76				99	18				20	8		
	09-27-78		36	72	108	12		70	20	90			SEVERE RUSTING OVER PLAIN BARS
	11-19-79				48					10			
	07-14-80	1			24	9							
		2			36								
		3			30	6							
		TOTAL			90	15							
		4									1		
		5									7		
		6									11		
		TOTAL									19		
	06-05-81	1			16								
		2			4								
		3			15								
		TOTAL			35								
		4								3			
		5								10			
		6								12			
		TOTAL								25			
	06-15-81				48					10			ALSO SIX RUST SPOTS
	09-12-84												ABANDONED
11	08-16-73												FINE CRACKS OVER 2 GALVANIZED
	09-11-73				50					62			
	09-09-74				90					90			1.0 SQ. IN. RUST SPOT ON PLAIN
	10-31-75				4								A LOT OF SMALL SPALLS

'SPALL' INFORMATION FOR GALVANIZED FIELD EXPOSURE SPECIMENS

BLOCK NO.	DATE	BAR NO.	UNCOATED CRACKS HAIRLINE (LIN IN)	UNCOATED CRACKS OPEN (LIN IN)	UNCOATED CRACKS TOTAL (LIN IN)	UNCOATED SPALLS (SQ IN)	UNCOATED HOLLOW AREA (SQ IN)	GALVANIZED CRACKS HAIRLINE (LIN IN)	GALVANIZED CRACKS OPEN (LIN IN)	GALVANIZED CRACKS TOTAL (LIN IN)	GALVANIZED SPALLS (SQ IN)	GALVANIZED HOLLOW AREA (SQ IN)	COMMENTS
	05-04-76				4								
	08-23-76				9					17			
	09-15-76				24	4				16			
	09-27-78		24	24	48			20	12	32			SOME PITTING
	11-19-79												PLAIN IS CRACKED BUT NOT OPEN
	07-14-80	1				12							
		4				2							
		6			6	6							
		TOTAL			6	8							
	06-05-81	1			3								
		6								5			
	06-15-81												PLAIN IS CRACKED 8UT NOT OPEN
	09-12-84				81	5				74	9		
12	08-16-73												FINE CRACKS OVER 3 GALV. BARS
	09-11-73				8					65			
	09-09-74				45			78	12	90			
	10-31-75				5								A LOT OF SMALL SPALLS
	05-04-76				5								
	08-23-76				12	4							
	09-15-76				12	6				6	2		
	09-27-78		1	3	4	15		9		9	6		
	11-19-79				12								
	07-14-80	1				10							
		2				2							
		TOTAL				12							
		4									4		
	06-05-81	1			11								
		2			2								
		TOTAL			13								
		4								1			
	06-15-81				12								
	09-12-84				24	4				34	2		
13	08-16-73												FINE CRACKS OVER 3 PLAIN, 1 GALV.
													8 RUST SPOTS OVER PLAIN
	09-11-73				90					12			6.0 SQ. IN. RUST SPOT OVER PLAIN
	09-09-74		80	10	90	18				30			14.0 SQ. IN. RUST SPOT OVER PLAIN
	10-31-75				29		20						
	05-04-76				29	3	20						
	08-23-76				31					19			
	09-15-76				36								
	09-27-78		60	38	98	12		24		24			A FEW RUST SPOTS
	11-19-79				32								

'SPALL' INFORMATION FOR GALVANIZED FIELD EXPOSURE SPECIMENS

BLOCK NO.	DATE	BAR NO.	UNCOATED CRACKS HAIRLINE (LIN IN)	UNCOATED CRACKS OPEN (LIN IN)	UNCOATED CRACKS TOTAL (LIN IN)	UNCOATED SPALLS (SQ IN)	UNCOATED HOLLOW AREA (SQ IN)	GALVANIZED CRACKS HAIRLINE (LIN IN)	GALVANIZED CRACKS OPEN (LIN IN)	GALVANIZED CRACKS TOTAL (LIN IN)	GALVANIZED SPALLS (SQ IN)	GALVANIZED HOLLOW AREA (SQ IN)	COMMENTS
	07-14-80	I			12	24							
		2				3							
		3				1							
		TOTAL			12	28							
	06-05-81	1			31								
		2			3								
		3			2								
		TOTAL			36								
	06-15-81				32								3 RUST SPOTS OVER GALVANIZED BARS
	09-12-84												ABANDONED
14	08-16-73												FINE CRACKS OVER 1 PLAIN, 2 GALV.
													8 TINY RUST SPOTS OVER PLAIN
	09-11-73				36					53			1.0 SQ. IN. RUST SPOT OVER PLAIN
	09-09-74				85					90			1I.5 SQ. IN. RUST SPOT OVER PLAIN
	10-31-75				30					29			
	05-04-76				30	6				29	7		
	08-23-76				10					25			
	09-15-76				50	16				30	13		
	09-27-78		46	60	106	35		56	42	98	I4	126	SEVERE RUSTING
	11-19-79				68					36			
	07-14-80	1			20	7							
		2			8	4							
		3				12							
		TOTAL			28	23							
		4									2		
		5								20			
		6								16	20		
		TOTAL								36	22		
	06-05-81	I			11								
		2			5								
		3			24								
		TOTAL			40								
		4								2			
		5								I			
		6								28			
		TOTAL								31			
	06-15-81				68					36			
	09-12-84												ABANDONED
15	09-12-84				60		100					80	
16	08-16-73				2								4 SMALL RUST SPOTS OVER PLAIN
	09-11-73				24								1.0 SQ. IN. RUST SPOT OVER PLAIN
	09-09-74		45	20	65					40			6.D SQ. IN. RUST SPOT OVER PLAIN

'SPALL' INFORMATION FOR GALVANIZED FIELD EXPOSURE SPECIMENS

BLOCK NO.	DATE	BAR NO.	UNCOATED CRACKS HAIRLINE (LIN IN)	UNCOATED CRACKS OPEN (LIN IN)	UNCOATED CRACKS TOTAL (LIN IN)	UNCOATED SPALLS (SQ IN)	UNCOATED HOLLOW AREA (SQ IN)	GALVANIZED CRACKS HAIRLINE (LIN IN)	GALVANIZED CRACKS OPEN (LIN IN)	GALVANIZED CRACKS TOTAL (LIN IN)	GALVANIZED SPALLS (SQ IN)	GALVANIZED HOLLOW AREA (SQ IN)	COMMENTS
	10-31-75				23								
	05-04-76				23	4					2		
	08-23-76				32	37							
	09-15-76				58	11				10	4		
	09-27-78		72	36	108			80	28	108	3		
	11-19-79				84					30			
	07-14-80	1			13	23							
		2			10								
		3			25								
		TOTAL			48	23							
		6								3	8		
	06-05-81	1			21								
		2			5								
		3			2								
		TOTAL			28								
		6								15			
	06-15-81				84					30			
	09-12-84												ABANDONED
17	08-16-73												FINE CRACKS OVER 2 PLAIN, 1 GALV.
	09-11-73				40					29			0.75 SQ. IN. RUST SPOT OVER PLAIN
	09-09-74				73					18			11.0 SQ. IN. RUST SPOT OVER PLAIN
	10-31-75				25								
	05-04-76				25	6							
	08-23-76				46	59							
	09-15-76				56	40				12	5		
	09-27-78		40	72	112			90	18	108	4		
	11-19-79				90					25			
	07-14-80	1			4	32							
		2			8	10							
		3			16	20							
		TOTAL			28	62							
		4								10	1		
		5									6		
		6								3	18		
		TOTAL								13	25		
	06-05-81	1			32								
		2			16								
		3			24								
		TOTAL			72								
		4								2			
		5								5			
		6								20			

'SPALL' INFORMATION FOR GALVANIZED FIELD EXPOSURE SPECIMENS

BLOCK NO.	DATE	BAR NO.	UNCOATED CRACKS HAIRLINE (LIN IN)	UNCOATED CRACKS OPEN (LIN IN)	UNCOATED CRACKS TOTAL (LIN IN)	UNCOATED SPALLS (SQ IN)	UNCOATED HOLLOW AREA (SQ IN)	GALVANIZED CRACKS HAIRLINE (LIN IN)	GALVANIZED CRACKS OPEN (LIN IN)	GALVANIZED CRACKS TOTAL (LIN IN)	GALVANIZED SPALLS (SQ IN)	GALVANIZED HOLLOW AREA (SQ IN)	COMMENTS
		TOTAL								27			
	06-15-81				90					25			
	09-12-84												ABANDONED
18	09-27-78												CENTER PLAIN BAR CRACKED & SPALLED
19	09-09-74									10			
	05-04-76					2					1		
	09-15-76				12	6							
	09-27-78		3	24	27								
	11-19-79				20								
	07-14-80	3			8	12							
	06-05-81	2			1								
		3			10								
	06-15-81				20								
	09-12-84				72	10				36			
20	08-16-73							1		1			
	09-11-73				18					54			
	09-09-74		35	3	38					67			
	09-15-76				24					2			
	09-27-78		18	18	36			12	15	27			
	11-19-79				17								
	07-14-80	1			12	8							
		3				2							
		TOTAL			12	10							
		6								12	7		
	06-15-81				17								
	09-12-84				72	5				108			
21	08-16-73												FINE CRACKS ON 2 PLAIN, 2 GALV.
													3 SMALL RUST SPOTS OVER PLAIN
	09-11-73				35					44			0.75 SQ. IN. RUST SPOT DVER PLAIN
	09-09-74				67					28			1.25 SQ. IN. RUST SPOT OVER PLAIN
	05-04-76										1		
	08-23-76				12								
	09-15-76				26	12	12			3	1		
	09-27-78			34	34	20		44	12	56	1		
	11-19-79				34					19			
	07-14-80	1			35	1							
		2			20	4							
		3			12	10							
		TOTAL			67	15							
		4									1		
		6								12	8		
		TOTAL								12	9		

<u>Appendix D</u> Visual Observations (Continued)

'SPALL' INFORMATION FOR GALVANIZED FIELD EXPOSURE SPECIMENS

BLOCK NO.	DATE	BAR NO.	UNCOATED CRACKS HAIRLINE (LIN IN)	UNCOATED CRACKS OPEN (LIN IN)	UNCOATED CRACKS TOTAL (LIN IN)	UNCOATED SPALLS (SQ IN)	UNCOATED HOLLOW AREA (SQ IN)	GALVANIZED CRACKS HAIRLINE (LIN IN)	GALVANIZED CRACKS OPEN (LIN IN)	GALVANIZED CRACKS TOTAL (LIN IN)	GALVANIZED SPALLS (SQ IN)	GALVANIZED HOLLOW AREA (SQ IN)	COMMENTS
	06-05-81	1			2								
		2			7								
		TOTAL			9								
		4								1			
		6								6			
		TOTAL								7			
	06-15-81				34					19			
	09-12-84												ABANDONED
22	09-11-73									6			
	09-09-74				36					90			0.5 SQ. IN. RUST SPOT OVER PLAIN
	10-31-75				20					6			TOP HAS SEVERAL SMALL SPALLS
	05-04-76					21				6			
	09-27-78			20	20			48	8	56	1		6 SPOTS OF RUST
	11-19-79				5								
	06-15-81				5								
	09-12-84				72					108			
23	09-11-73				10								BARS 1-3 ARE PLAIN
	09-09-74				18								BARS 4-6 HAVE 2 COATS OF LINSEED-MINERAL SPIRIT
	05-04-76				20					6			
	08-23-76												ALL PLAIN BARS
	09-27-78		92	30	122	14							
	11-19-79				10								
	07-14-80	1				4							
		2				1							
		3			10	12							
		TOTAL			10	17							
	06-05-81	3			11								
	06-15-81				10								
	09-12-84				108	16				108			
24	08-16-73												ONE FINE CRACK IN LINSEED SECTION
	09-09-74				3					36			ALL PLAIN BARS
	10-31-75									12			BARS 1-3 ARE PLAIN
	05-04-76					1					12		BARS 4-6 HAVE 2 COATS OF LINSEED-MINERAL SPIRIT
	08-23-76				23								
	09-27-78		56	60	116	39							
	11-19-79				8								
	07-14-80	1			12								
		3				1							
		TOTAL			12	1							
	06-05-81	1			7								
		6								35			
	06-15-81				8								

'SPALL' INFORMATION FOR GALVANIZED FIELD EXPOSURE SPECIMENS

BLOCK NO.	DATE	BAR NO.	UNCOATED CRACKS HAIRLINE (LIN IN)	UNCOATED CRACKS OPEN (LIN IN)	UNCOATED CRACKS TOTAL (LIN IN)	UNCOATED SPALLS (SQ IN)	UNCOATED HOLLOW AREA (SQ IN)	GALVANIZED CRACKS HAIRLINE (LIN IN)	GALVANIZED CRACKS OPEN (LIN IN)	GALVANIZED CRACKS TOTAL (LIN IN)	GALVANIZED SPALLS (SQ IN)	GALVANIZED HOLLOW AREA (SQ IN)	COMMENTS
	09-12-84				91	7				80	36		
25	09-09-74								30	30			OPEN CRACKS ARE IN THE CORNER
	10-31-75									29			ALL PLAIN BARS
	05-04-76									29	4		BARS 1-3 ARE PLAIN
	08-23-76				36								BARS 4-6 HAVE 2 COATS OF
	09-27-78		16	36	52	15							LINSEED-MINERAL SPIRIT
	11-19-79									28			
	07-14-80	6								36			
	06-05-81	6								36			
	06-15-81									28			
	09-12-84				45					60	39		
26	10-31-75												MANY SMALL SPALLS ALL OVER DECK
	05-04-76												DECK HAS SEVERAL PITS
	09-27-78							24	12	36			ALL GALVANIZED BARS
	07-14-80	1				12							MANY STONE POPOUTS 1/4 TO 1/2" DEEP
		2				4							BARS 1-3 ARE PLAIN
		TOTAL				16							BARS 4-6 HAVE POTASSIUM
	06-05-81	1			5								DICHROMATE TREATMENT
		3			2								
		TOTAL			7								
	09-12-84				84	3				108	5		
27	08-16-73												VERY BADLY SCALED
	10-31-75												SLAB TOP DETERIORATED TO BAR TOPS
	05-04-76												ABANDONED
28	08-16-73												VERY BADLY SCALED
	10-31-75												SLAB TOP DETERIORATED TO BAR TOPS
	05-04-76												ABANDONED
29	08-16-73												VERY BADLY SCALED
	10-31-75												SLAB TOP DETERIORATED TO BAR TOPS
	05-04-76												ABANDONED
30	09-09-74				10	10					9		SPALLS ARE INCIPIENT
	10-31-75				49		144			4			
	05-04-76				49	4	144			4			
	08-23-76												
	09-15-76				8	10	8				8	30	NO LAP
	09-15-76				50	12	140						LAP
	09-27-78		80	56	136	30		39	10	49	7		THIS BLOCK HAS 6 PLAIN, 3 GALV.
	11-19-79				56								
	07-14-80	1			24	24							
		2			6	6							
		3				4							
		4				14							

'SPALL' INFORMATION FOR GALVANIZED FIELD EXPOSURE SPECIMENS

BLOCK NO.	DATE	BAR NO.	UNCOATED CRACKS					GALVANIZED CRACKS					COMMENTS
			HAIRLINE (LIN IN)	OPEN (LIN IN)	TOTAL (LIN IN)	SPALLS (SQ IN)	HOLLOW AREA (SQ IN)	HAIRLINE (LIN IN)	OPEN (LIN IN)	TOTAL (LIN IN)	SPALLS (SQ IN)	HOLLOW AREA (SQ IN)	
		5				2							
		6				3							
		TOTAL			30	53							
		7									10		
		8									14		
		TOTAL									24		
	06-05-81	1			48								
		2			7								
		3			4								
		4			11								
		5			5								
		6			2								
		TOTAL			77								
		7								13			
		8								10			
		TOTAL								23			
	06-15-81				56								SOME SPALLS BUT NO CRACKS IN GALV.
													MANY RUST SPOTS
	09-12-84												ABANOONEO
31	09-09-74									9			9 RUST SPOTS ON PLAIN, 2 ON GALV.
	09-15-76									8			
	09-27-78							12		12			A FEW POPOUTS BUT NO SPALLS
	11-19-79												A FEW RUST SPOTS
	07-14-80												FEW RUST SPOTS,NO POPOUTS OR SPALLS
	06-15-81												A FEW RUST SPOTS ON EACH KIND
	09-12-84				72	12	225			27			
32	05-04-76					1							
	09-27-78												A FEW POPOUTS BUT NO SPALLS
	07-14-80												FEW RUST SPOTS,NO POPOUTS OR SPALLS
	09-12-84				18					36			
33	09-27-78							10	6	16			A FEW POPOUTS BUT NO SPALLS
	07-14-80												FEW RUST SPOTS,NO POPOUTS OR SPALLS
34	05-04-76					1					3		
	09-27-78												A FEW POPOUTS BUT NO SPALLS
	07-14-80												FEW RUST SPOTS,NO POPOUTS OR SPALLS
35	09-27-78												A FEW POPOUTS BUT NO SPALLS
	07-14-80												FEW RUST SPOTS,NO POPOUTS OR SPALLS
36	05-04-76					3					1		
	09-27-78												A FEW POPOUTS BUT NO SPALLS
	07-14-80												FEW RUST SPOTS,NO POPOUTS OR SPALLS

'SPALL' INFORMATION FOR EPOXY COATED FIELD EXPOSURE SPECIMENS

BLOCK NO.	DATE	BARS 1 - 3 CRACKS TOTAL (LIN IN)	BARS 1 - 3 SPALLS (SQ IN)	BARS 1 - 3 HOLLOW AREA (SQ IN)	BARS 4 - 6 CRACKS TOTAL (LIN IN)	BARS 4 - 6 SPALLS (SQ IN)	BARS 4 - 6 HOLLOW AREA (SQ IN)	OVERALL CRACKS TOTAL (LIN IN)	OVERALL SPALLS (SQ IN)	OVERALL HOLLOW AREA (SQ IN)	COMMENTS
1	09-28-78										TOP PITTED ABOUT 40%
	09-12-84	72	13					72	13		
2	09-12-84	42			32			74			
4	09-28-78								4		SPALLS ARE ACTUALLY POPOUTS
	09-12-84				18	3		18	3		
6	09-28-78								6		SPALLS ARE ACTUALLY POPOUTS
7	09-12-84	36			72			108			
8	09-12-84				6	4		6	4		
10	09-28-78								6		
11	09-12-84		3						3		
12	09-28-78								2		SEVERAL POPOUTS BUT NO CRACKS
	09-12-84	22	5					22	5		
15	09-28-78							15	2		2 RUST SPOTS OVER CRACKS;PLAIN BARS
	09-12-84	108	27		108	32		216	59		
17	09-28-78										MUCH PITTING (POPOUTS); ALL GALV.
	09-12-84	12			60	14		72	14		
19	09-28-78								6		
	09-12-84	7	2					7	2		
20	09-28-78								2		SPALL COULD BE CALLED A POPOUT
	09-12-84	10			12	2		22	2		
21	09-28-78								7		SPALL COULD BE CALLED A POPOUT
23	09-28-78								8		ALL GALVANIZED
	09-12-84	20			36			56			
25	09-12-84					2			2		
26	09-12-84	36			36			72			
27	09-12-84				48			48			
28	09-28-78								4		SEVERAL POPOUTS
	09-12-84	36	8					36	8		
29	09-28-78										SEVERAL POPOUTS
	09-12-84	72	12		72	10		144	22		
30	09-12-84				6			6			
31	09-28-78								4		************************************
	09-12-84	46						46			THE SPALLS APPEAR TO BE POPOUTS
33	09-12-84	14			72			86			RATHER THAN SPALLS, CAUSED BY
34	09-12-84	36			72	8		108	8		PERHAPS TOO MUCH STONE IN THE MIX.
36	09-28-78								25		MOST OF THE DECKS HAVE STONE BELOW
	09-12-84	108	4		108	2		216	6		THE POPOUT.
37	09-12-84	108	2		108	5		216	7		************************************

Appendix E

Appendix E Half Cell Readings for Field Specimens
Galvanized--68F103 and Epoxy Coated--73F131

Data for each simulated bridge deck slab is recorded here in the format used as input for the fortran program that analyzed the half cell values for the various categories of specimens. The slab number, date of reading, number of rows and columns, and temperature at the time of readings (^{0}F) proceeds the half cell values (negative volts). Missing data is indicated with a -9.0.

```
 1 GALVANIZED06/15/710106
.38 .38 .38 .45 .45 .45
 2 GALVANIZED06/15/710106
.45 .45 .45 .50 .50 .50
 3 GALVANIZED06/15/710106
.57 .57 .57 .84 .84 .84
 4 GALVANIZED06/15/710106
.41 .41 .41 .40 .40 .40
 5 GALVANIZED06/15/710106
.60 .60 .60 .73 .73 .73
 6 GALVANIZED06/15/710106
.48 .48 .48 .57 .57 .57
 7 GALVANIZED06/15/710106
.53 .53 .53 .60 .60 .60
 8 GALVANIZED06/15/710106
.47 .47 .47 .67 .67 .67
 9 GALVANIZED06/15/710106
.60 .60 .60 .50 .50 .50
10 GALVANIZED06/15/710106
.58 .58 .58 .90 .90 .90
11 GALVANIZED06/15/710106
.53 .53 .53 .77 .77 .77
12 GALVANIZED06/15/710106
.49 .49 .49 .50 .50 .50
13 GALVANIZED06/15/710106
.53 .53 .53 .49 .49 .49
14 GALVANIZED06/15/710106
.57 .57 .57 .70 .70 .70
15 GALVANIZED06/15/710106
.42 .42 .42 .40 .40 .40
16 GALVANIZED06/15/710106
.60 .60 .60 .82 .82 .82
17 GALVANIZED06/15/710106
.52 .52 .52 .50 .50 .50
18 GALVANIZED06/15/710106
.38 .38 .38 .42 .42 .42
19 GALVANIZED06/15/710106
.44 .44 .44 .50 .50 .50
20 GALVANIZED06/15/710106
.46 .46 .46 .60 .60 .60
21 GALVANIZED06/15/710106
.56 .56 .56 .78 .78 .78
22 GALVANIZED06/15/710106
.60 .60 .60 .60 .60 .60
23 GALVANIZED06/15/710106
.42 .42 .42 .36 .36 .36
24 GALVANIZED06/15/710106
.43 .43 .43 .50 .50 .50
25 GALVANIZED06/15/710106
.36 .36 .36 .44 .44 .44
26 GALVANIZED06/15/710106
.61 .61 .61 .62 .62 .62
27 GALVANIZED06/15/710106
.85 .85 .85 .92 .92 .92
28 GALVANIZED06/15/710106
.95 .95 .95 .99 .99 .99
29 GALVANIZED06/15/710106
.66 .66 .66 .73 .73 .73
30 GALVANIZED06/15/710106
.60 .60 .60 .68 .68 .68
31 GALVANIZED06/15/710106
.51 .51 .51 .59 .59 .59
32 GALVANIZED06/15/710106
.44 .44 .44 .41 .41 .41
33 GALVANIZED06/15/710106
.31 .31 .31 .27 .27 .27
34 GALVANIZED06/15/710106
.28 .28 .28 .28 .28 .28
35 GALVANIZED06/15/710106
.27 .27 .27 .30 .30 .30
36 GALVANIZED06/15/710106
.29 .29 .29 .35 .35 .35
30 GALVANIZED07/15/720106
.68 .68 .68 .57 .57 .57
31 GALVANIZED07/15/720106
.57 .57 .57 .62 .62 .62
32 GALVANIZED07/15/720106
.47 .47 .47 .53 .53 .53
33 GALVANIZED07/15/720106
.42 .42 .42 .36 .36 .36
34 GALVANIZED07/15/720106
.34 .34 .34 .34 .34 .34
35 GALVANIZED07/15/720106
.34 .34 .34 .37 .37 .37
36 GALVANIZED07/15/720106
.40 .40 .40 .43 .43 .43
 1 GALVANIZED08/15/730106
.46 .46 .46 .50 .50 .50
 2 GALVANIZED08/15/730106
.41 .41 .41 .48 .48 .48
```

```
 3 GALVANIZED08/15/730106
 .57 .57 .57 .59 .59 .59
 4 GALVANIZED08/15/730106
 .38 .38 .38 .47 .47 .47
 5 GALVANIZED08/15/730106
 .46 .46 .46 .41 .41 .41
 6 GALVANIZED08/15/730106
 .47 .47 .47 .47 .47 .47
 7 GALVANIZED08/15/730106
 .45 .45 .45 .51 .51 .51
 8 GALVANIZED08/15/730106
 .43 .43 .43 .52 .52 .52
 9 GALVANIZED08/15/730106
 .44 .44 .44 .62 .62 .62
10 GALVANIZED08/15/730106
 .54 .54 .54 .54 .54 .54
11 GALVANIZED08/15/730106
 .42 .42 .42 .46 .46 .46
12 GALVANIZED08/15/730106
 .42 .42 .42 .47 .47 .47
13 GALVANIZED08/15/730106
 .54 .54 .54 .50 .50 .50
14 GALVANIZED08/15/730106
 .50 .50 .50 .49 .49 .49
15 GALVANIZED08/15/730106
 .50 .50 .50 .53 .53 .53
16 GALVANIZED08/15/730106
 .67 .67 .67 .64 .64 .64
17 GALVANIZED08/15/730106
 .67 .67 .67 .60 .60 .60
18 GALVANIZED08/15/730106
 .46 .46 .46 .49 .49 .49
19 GALVANIZED08/15/730106
 .55 .55 .55 .56 .56 .56
20 GALVANIZED08/15/730106
 .55 .55 .55 .66 .66 .66
21 GALVANIZED08/15/730106
 .65 .65 .65 .61 .61 .61
22 GALVANIZED08/15/730106
 .53 .53 .53 .62 .62 .62
23 GALVANIZED08/15/730106
 .49 .49 .49 .47 .47 .47
24 GALVANIZED08/15/730106
 .48 .48 .48 .58 .58 .58
25 GALVANIZED08/15/730106
 .37 .37 .37 .39 .39 .39
26 GALVANIZED08/15/730106
 .51 .51 .51 .53 .53 .53
27 GALVANIZED08/15/730106
 .69 .69 .69 .67 .67 .67
28 GALVANIZED08/15/730106
 .62 .62 .62 .61 .61 .61
29 GALVANIZED08/15/730106
 .50 .50 .50 .47 .47 .47
30 GALVANIZED08/15/730106
 .59 .59 .59 .51 .51 .51
31 GALVANIZED08/15/730106
 .54 .54 .54 .52 .52 .52
32 GALVANIZED08/15/730106
 .49 .49 .49 .47 .47 .47
33 GALVANIZED08/15/730106
 .41 .41 .41 .40 .40 .40
34 GALVANIZED08/15/730106
 .37 .37 .37 .34 .34 .34
35 GALVANIZED08/15/730106
 .34 .34 .34 .38 .38 .38
36 GALVANIZED08/15/730106
 .41 .41 .41 .44 .44 .44
 1 GALVANIZED08/05/740206
 .38 .40 .40 .46 .47 .43
 .45 .44 .40 .46 .46 .44
 2 GALVANIZED08/05/740206
 .50 .46 .44 .48 .51 .55
 .50 .46 .45 .50 .52 .56
 3 GALVANIZED08/05/740206
 .60 .62 .56 .72 .73 .79
 .60 .63 .57 .70 .72 .71
 4 GALVANIZED08/05/740206
 .48 .42 .39 .46 .48 .57
 .40 .40 .40 .40 .42 .45
 5 GALVANIZED08/05/740206
 .54 .58 .58 .62 .56 .57
 .56 .58 .62 .58 .56 .58
 6 GALVANIZED08/05/740206
 .54 .50 .50 .61 .58 .62
 .55 .50 .50 .56 .56 .59
 7 GALVANIZED08/05/740206
 .45 .52 .51 .50 .48 .56
 .48 .46 .47 .50 .47 .54
 8 GALVANIZED08/05/740206
 .51 .45 .44 .53 .64 .64
 .50 .45 .39 .51 .56 .63
 9 GALVANIZED08/05/740206
 .55 .53 .47 .53 .59 .68
 .52 .45 .45 .60 .64 .66
10 GALVANIZED08/05/740206
 .60 .55 .55 .62 .63 .66
 .63 .56 .56 .64 .67 .66
11 GALVANIZED08/05/740206
 .52 .49 .44 .57 .52 .59
 .53 .52 .48 .52 .50 .58
12 GALVANIZED08/05/740206
```

```
 .54 .48 .44 .47 .50 .53
 .47 .46 .44 .44 .48 .51
13 GALVANIZED08/05/740206
 .64 .58 .56 .63 .58 .62
 .60 .61 .58 .64 .64 .54
14 GALVANIZED08/05/740206
 .56 .54 .56 .58 .63 .62
 .54 .52 .51 .60 .60 .62
15 GALVANIZED08/05/740206
 .46 .40 .44 .52 .53 .52
 .56 .53 .46 .56 .56 .54
16 GALVANIZED08/05/740206
 .64 .57 .58 .62 .58 .56
 .56 .58 .53 .59 .61 .58
17 GALVANIZED08/05/740206
 .62 .61 .58 .72 .62 .62
 .63 .61 .56 .71 .68 .69
18 GALVANIZED08/05/740206
 .36 .34 .35 .38 .37 .40
 .20 .38 .36 .40 .42 .44
19 GALVANIZED08/05/740206
 .53 .48 .49 .48 .50 .55
 .48 .47 .50 .53 .54 .56
20 GALVANIZED08/05/740206
 .55 .48 .54 .60 .62 .66
 .52 .50 .52 .56 .61 .70
21 GALVANIZED08/05/740206
 .66 .58 .60 .58 .60 .66
 .64 .60 .61 .60 .60 .65
22 GALVANIZED08/05/740206
 .30 .28 .30 .60 .63 .66
 .30 .27 .29 .60 .62 .66
23 GALVANIZED08/05/740206
 .48 .53 .54 .53 .52 .50
 .46 .46 .49 .52 .47 .46
24 GALVANIZED08/05/740206
 .42 .45 .46 .53 .55 .60
 .48 .45 .49 .55 .58 .60
25 GALVANIZED08/05/740206
 .46 .41 .47 .49 .53 .54
 .38 .43 .46 .51 .56 .59
26 GALVANIZED08/05/740206
 .46 .42 .41 .46 .46 .48
 .46 .41 .46 .44 .46 .48
27 GALVANIZED08/05/740206
 .52 .60 .56 .52 .54 .54
 .54 .64 .50 .52 .54 .51
28 GALVANIZED08/05/740206
 .64 .61 .62 .54 .56 .56
 .64 .62 .60 .56 .58 .60
```

```
29 GALVANIZED08/05/740206
 .58 .55 .57 .52 .54 .54
 .63 .59 .59 .51 .54 .56
31 GALVANIZED08/05/740206
 .51 .55 .57 .51 .49 .52
 .53 .44 .55 .50 .50 .48
32 GALVANIZED08/05/740206
 .47 .46 .44 .46 .42 .48
 .44 .50 .44 .41 .40 .39
33 GALVANIZED08/05/740206
 .40 .36 .36 .35 .35 .34
 .36 .35 .33 .35 .34 .32
34 GALVANIZED08/05/740206
 .30 .28 .30 .31 .32 .32
 .30 .30 .28 .27 .28 .28
35 GALVANIZED08/05/740206
 .32 .30 .28 .30 .30 .33
 .30 .30 .29 .29 .30 .32
36 GALVANIZED08/05/740206
 .30 .30 .30 .48 .52 .53
 .30 .30 .30 .45 .47 .50
37 GALVANIZED00/00/000101 32.2
  .00
 1 GALVANIZED09/15/750206
 .58 .46 .42 .40 .39 .27
 .48 .38 .42 .43 .40 .26
 2 GALVANIZED09/15/750206
 .49 .51 .49 .45 .57 .54
 .49 .46 .47 .42 .55 .54
 3 GALVANIZED09/15/750206
 .51 .54 .50 .54 .50 .54
 .47 .57 .51 .51 .48 .53
 4 GALVANIZED09/15/750206
 .48 .44 .49 .48 .49 .54
 .53 .41 .47 .54 .62 .63
 5 GALVANIZED09/15/750206
 .60 .58 .50 .52 .54 .48
 .61 .50 .57 .53 .52 .56
 6 GALVANIZED09/15/750206
 .50 .50 .35 .50 .48 .54
 .51 .53 .29 .49 .49 .52
 7 GALVANIZED09/15/750206
 .50 .51 .48 .53 .50 .49
 .50 .52 .49 .49 .47 .46
 8 GALVANIZED09/15/750206
 .57 .52 .42 .58 .69 .65
 .53 .50 .43 .58 .69 .61
 9 GALVANIZED09/15/750206
 .55 .53 .51 .56 .78 .64
```

```
  .50 .46 .48 .56 .79 .63
10 GALVANIZED09/15/750206
  .57 .56 .55 .56 .53 .54
  .52 .58 .51 .57 .53 .55
11 GALVANIZED09/15/750206
  .58 .54 .48 .51 .55 .53
  .57 .54 .51 .52 .52 .51
12 GALVANIZED09/15/750206
  .54 .53 .51 .53 .51 .50
  .53 .52 .51 .51 .51 .52
13 GALVANIZED09/15/750206
  .64 .67 .62 .56 .58 .56
  .58 .61 .56 .54 .59 .50
14 GALVANIZED09/15/750206
  .52 .49 .50 .52 .56 .53
  .55 .48 .51 .50 .55 .47
15 GALVANIZED09/15/750206
  .64 .64 .57 .59 .56 .59
  .54 .65 .54 .61 .59 .60
16 GALVANIZED09/15/750206
  .56 .52 .52 .53 .57 .66
  .57 .51 .56 .52 .54 .58
17 GALVANIZED09/15/750206
  .54 .53 .53 .50 .51 .63
  .54 .54 .54 .48 .49 .62
18 GALVANIZED09/15/750206
  .40 .38 .42 .42 .42 .47
  .34 .32 .34 .32 .35 .36
19 GALVANIZED09/15/750206
  .73 .70 .70 .58 .54 .57
  .74 .68 .68 .59 .54 .52
20 GALVANIZED09/15/750206
  .53 .58 .57 .56 .58 .58
  .56 .58 .56 .57 .55 .57
21 GALVANIZED09/15/750206
  .53 .53 .58 .48 .51 .52
  .42 .40 .44 .51 .47 .49
22 GALVANIZED09/15/750206
  .52 .49 .51 .54 .58 .52
  .50 .48 .53 .54 .64 .57
23 GALVANIZED09/15/750206
  .46 .49 .53 .51 .54 .55
  .40 .43 .53 .51 .51 .56
24 GALVANIZED09/15/750206
  .38 .40 .50 .60 .62 .58
  .53 .46 .52 .60 .62 .60
25 GALVANIZED09/15/750206
  .53 .42 .46 .44 .62 .63
  .40 .42 .46 .59 .65 .64
26 GALVANIZED09/15/750206
  .54 .48 .45 .51 .45 .55
  .50 .47 .46 .54 .48 .60
27 GALVANIZED09/15/750206
  .46 .45 .44 .41 .46 .37
  .45 .42 .39 .44 .42 .46
28 GALVANIZED09/15/750206
  .75 .60 .52 .55 .62 .76
  .78 .66 .56 .60 .68 .79
29 GALVANIZED09/15/750206
  .46 .43 .40 .44 .41 .46
  .41 .44 .44 .44 .42 .42
30 GALVANIZED09/15/750306
  .54 .49 .48 .42 .43 .41
  .48 .49 .44 .44 .40 .40
  .44 .41 .40 .40 .39 .36
31 GALVANIZED09/15/750206
  .34 .34 .51 .50 .50 .44
  .38 .34 .42 .48 .49 .48
32 GALVANIZED09/15/750206
  .43 .51 .41 .45 .40 .30
  .45 .48 .41 .47 .40 .41
33 GALVANIZED09/15/750206
  .34 .34 .35 .34 .33 .32
  .39 .38 .38 .38 .37 .35
34 GALVANIZED09/15/750206
  .30 .31 .28 .28 .29 .29
  .31 .32 .31 .33 .37 .36
35 GALVANIZED09/15/750206
  .32 .31 .30 .30 .31 .33
  .31 .28 .30 .31 .32 .31
36 GALVANIZED09/15/750206
  .37 .39 .42 .41 .41 .43
  .34 .33 .37 .45 .52 .53
37 GALVANIZED00/00/000101 32.2
  .00
  1 GALVANIZED05/04/760206
  .58 .56 .58 .50 .44 .38
  .42 .42 .53 .50 .44 .36
  2 GALVANIZED05/04/760206
  .68 .68 .64 .62 .72 .50
  .64 .68 .62 .60 .70 .64
  3 GALVANIZED05/04/760206
  .64 .64 .61 .61 .66 .62
  .64 .62 .62 .58 .65 .60
  4 GALVANIZED05/04/760206
  .68 .56 .64 .64 .62 .64
  .70 .56 .64 .70 .76 .76
  5 GALVANIZED05/04/760206
  .50 .54 .52 .52 .50 .52
  .50 .52 .50 .51 .50 .50
  6 GALVANIZED05/04/760206
  .67 .65 .62 .58 .60 .58
```

```
 .61 .78 .58 .53 .56 .53
 7 GALVANIZED05/04/760206
 .62 .58 .62 .58 .52 .47
 .58 .56 .54 .54 .49 .48
 8 GALVANIZED05/04/760206
 .90 .62 .70 .68 .69 .65
 .74 .74 .70 .67 .70 .54
 9 GALVANIZED05/04/760206
 .40 .42 .40 .46 .60 .52
 .44 .50 .44 .47 .58 .50
10 GALVANIZED05/04/760206
 .45 .49 .47 .44 .46 .48
 .44 .46 .42 .46 .42 .44
11 GALVANIZED05/04/760206
 .44 .48 .42 .44 .41 .42
 .44 .46 .42 .44 .44 .44
12 GALVANIZED05/04/760206
 .53 .51 .44 .49 .44 .46
 .50 .51 .44 .50 .43 .42
13 GALVANIZED05/04/760206
 .50 .48 .45 .46 .62 .43
 .50 .48 .49 .48 .60 .46
14 GALVANIZED05/04/760206
 .54 .50 .47 .46 .49 .52
 .53 .49 .46 .45 .48 .53
15 GALVANIZED05/04/760206
 .60 .59 .60 .60 .47 .50
 .42 .40 .40 .44 .38 .40
16 GALVANIZED05/04/760206
 .59 .58 .54 .56 .56 .60
 .56 .60 .54 .55 .54 .57
17 GALVANIZED05/04/760206
 .40 .44 .44 .44 .40 .42
 .43 .49 .40 .40 .39 .44
18 GALVANIZED05/04/760206
 .32 .30 .32 .34 .33 .40
 .20 .16 .20 .22 .24 .26
19 GALVANIZED05/04/760206
 .46 .44 .42 .39 .45 .52
 .52 .52 .45 .42 .48 .52
20 GALVANIZED05/04/760206
 .51 .49 .48 .48 .46 .52
 .50 .46 .46 .46 .45 .49
21 GALVANIZED05/04/760206
 .48 .50 .47 .48 .46 .46
 .48 .46 .44 .49 .48 .49
22 GALVANIZED05/04/760206
 .46 .34 .38 .42 .43 .40
 .44 .30 .33 .38 .40 .38
23 GALVANIZED05/04/760206
 .26 .29 .33 .33 .31 .34
```

```
 .34 .39 .41 .36 .34 .33
24 GALVANIZED05/04/760206
 .35 .38 .32 .34 .39 .38
 .14 .19 .28 .30 .38 .32
25 GALVANIZED05/04/760206
 .19 .20 .26 .36 .38 .40
 .32 .28 .28 .36 .39 .33
26 GALVANIZED05/04/760206
 .38 .32 .36 .36 .33 .42
 .40 .32 .33 .31 .27 .38
27 GALVANIZED05/04/760206
 .30 .30 .28 .27 .26 .32
 .28 .28 .28 .27 .29 .32
28 GALVANIZED05/04/760206
 .30 .31 .26 .25 .24 .29
 .30 .31 .26 .22 .27 .28
29 GALVANIZED05/04/760206
 .28 .24 .28 .26 .24 .23
 .30 .22 .26 .22 .26 .27
31 GALVANIZED05/04/760206
 .62 .54 .58 .53 .54 .46
 .46 .53 .52 .42 .48 .44
32 GALVANIZED05/04/760206
 .50 .58 .52 .46 .41 .43
 .54 .58 .50 .50 .40 .48
33 GALVANIZED05/04/760206
 .39 .38 .40 .38 .36 .34
 .42 .40 .39 .40 .38 .39
34 GALVANIZED05/04/760206
 .36 .38 .36 .32 .32 .34
 .36 .36 .36 .36 .39 .44
35 GALVANIZED05/04/760206
 .35 .38 .36 .34 .37 .39
 .34 .35 .36 .36 .38 .39
36 GALVANIZED05/04/760206
 .41 .44 .46 .46 .45 .42
 .39 .40 .44 .54 .60 .60
 1 GALVANIZED08/07/810306
 .78 .72 .68 .62 .52 .52
 .78 .72 .68 .60 .52 .52
 .72 .68 .70 .64 .54 .40
 2 GALVANIZED08/07/810306
 .60 .60 .58 .62 .62 .62
 .60 .58 .56 .56 .60 .62
 .60 .58 .60 .60 .60 .60
 3 GALVANIZED08/07/810306
 .54 .58 .56 .60 .56 .54
 .50 .52 .48 .54 .52 .54
 .48 .60 .56 .58 .58 .54
 4 GALVANIZED08/07/810306
 .60 .58 .60 .60 .60 .62
```

```
 .60 .58 .56 .60 .60 .58
 .60 .60 .60 .60 .60 .58
 5 GALVANIZED08/07/810306
 .52 .52 .46 .46 .50 .48
 .40 .46 .50 .44 .42 .44
 .50 .48 .46 .50 .50 .48
 6 GALVANIZED08/07/810306
 .60 .64 .60 .60 .60 .60
 .64 .62 .60 .58 .56 .60
 .56 .62 .58 .58 .56 .60
 7 GALVANIZED08/07/810306
 .62 .66 .66 .62 .64 .66
 .66 .62 .62 .60 .60 .62
 .64 .62 .60 .60 .58 .56
 8 GALVANIZED08/07/810306
 .58 .56 .54 .54 .56 .56
 .58 .56 .54 .54 .52 .56
 .58 .56 .56 .54 .56 .56
 9 GALVANIZED08/07/810306
 .72 .68 .68 .70 .72 .68
 .66 .70 .68 .68 .68 .68
 .68 .66 .68 .68 .68 .68
10 GALVANIZED08/07/810306
 .52 .51 .48 .50 .50 .46
 .48 .48 .46 .48 .46 .50
 .52 .46 .46 .48 .48 .48
11 GALVANIZED08/07/810306
 .56 .58 .54 .56 .56 .58
 .56 .56 .54 .54 .56 .54
 .56 .54 .54 .54 .58 .56
12 GALVANIZED08/07/810306
 .62 .60 .60 .60 .58 .60
 .56 .58 .56 .56 .56 .56
 .52 .52 .52 .54 .54 .54
13 GALVANIZED08/07/810306
 .60 .64 .62 .54 .52 .52
 .60 .54 .54 .54 .52 .48
 .58 .58 .54 .54 .54 .50
14 GALVANIZED08/07/810306
 .60 .64 .58 .62 .64 .56
 .56 .62 .54 .54 .54 .56
 .56 .54 .54 .52 .54 .54
15 GALVANIZED08/07/810306
 .62 .62 .60 .58 .60 .60
 .60 .58 .58 .54 .52 .54
 .56 .54 .56 .56 .52 .52
16 GALVANIZED08/07/810306
 .54 .56 .56 .56 .52 .50
 .46 .56 .54 .52 .52 .54
 .50 .56 .48 .52 .52 .52
17 GALVANIZED08/07/810306
 .42 .54 .48 .50 .54 .50
 .46 .50 .44 .50 .52 .52
 .44 .54 .52 .54 .52 .52
18 GALVANIZED08/07/810306
 .62 .58 .58 .58 .58 .58
 .56 .52 .50 .50 .56 .50
 .52 .44 .30 .40 .44 .50
19 GALVANIZED08/07/810306
 .72 .70 .66 .64 .66 .66
 .64 .62 .60 .58 .60 .62
 .62 .60 .62 .56 .58 .58
20 GALVANIZED08/07/810306
 .62 .58 .56 .56 .58 .56
 .58 .58 .54 .54 .58 .56
 .60 .60 .56 .52 .54 .56
21 GALVANIZED08/07/810306
 .50 .56 .52 .50 .50 .54
 .54 .44 .42 .48 .48 .50
 .52 .52 .54 .50 .54 .56
22 GALVANIZED08/07/810306
 .50 .56 .52 .54 .54 .54
 .52 .50 .50 .52 .54 .52
 .52 .52 .50 .52 .50 .54
23 GALVANIZED08/07/810306
 .72 .74 .72 .68 .68 .68
 .70 .68 .68 .62 .68 .68
 .68 .66 .68 .66 .66 .66
24 GALVANIZED08/07/810306
 .58 .52 .52 .52 .52 .46
 .58 .52 .50 .44 .48 .50
 .48 .50 .54 .50 .52 .50
25 GALVANIZED08/07/810306
 .82 .86 .86 .88 .86 .82
 .82 .84 .84 .86 .88 .82
 .84 .82 .86 .86 .90 .82
26 GALVANIZED08/07/810306
 .74 .72 .70 .72 .72 .74
 .72 .70 .66 .64 .70 .68
 .72 .72 .68 .68 .68 .68
31 GALVANIZED08/07/810306
 .50 .46 .52 .48 .46 .38
 .44 .48 .56 .40 .42 .48
 .56 .52 .48 .52 .48 .54
32 GALVANIZED08/07/810306
 .42 .50 .40 .38 .38 .38
 .38 .44 .42 .44 .38 .42
 .54 .54 .44 .44 .42 .48
33 GALVANIZED08/07/810306
 .36 .36 .40 .34 .32 .36
 .36 .46 .36 .36 .38 .40
 .50 .42 .38 .42 .38 .38
```

```
34 GALVANIZED08/07/810306
 .34 .34 .32 .32 .34 .40
 .34 .34 .32 .34 .38 .34
 .36 .34 .32 .34 .34 .34
35 GALVANIZED08/07/810306
 .46 .48 .42 .40 .44 .48
 .32 .34 .34 .36 .40 .38
 .32 .30 .32 .38 .42 .40
36 GALVANIZED08/07/810306
 .50 .50 .50 .50 .48 .42
 .36 .36 .38 .42 .46 .44
 .36 .36 .42 .54 .54 .54
 1 GALVANIZED09/13/840306
 .66 .65 .64 .57 .44 .38
 .66 .62 .54 .54 .48 .45
-9.0 .00 .61 .57 .50-9.0
 2 GALVANIZED09/13/840306
 .65 .64 .65 .66 .67 .68
 .66 .67 .66 .68 .69 .69
 .66 .65 .64 .70 .69 .70
 4 GALVANIZED09/13/840306
 .66 .62 .66 .67 .65 .66
 .65 .61 .65 .65 .64 .68
 .66 .64 .67 .65 .64 .64
 6 GALVANIZED09/13/840306
-9.0 .59 .61 .59 .59 .60
 .64 .63 .60 .59 .60 .59
 .60 .61 .57 .59 .64 .60
 7 GALVANIZED09/13/840306
 .66 .63 .61 .62 .65 .67
 .66 .56 .60 .63 .68 .67
 .62 .64 .63 .63 .65 .65
 8 GALVANIZED09/13/840306
 .63 .61 .60 .59 .61 .62
 .65 .59 .67 .65 .63 .64
 .63 .61 .63 .60 .59 .60
 9 GALVANIZED09/13/840306
 .65 .63 .66 .64 .63 .63
 .68 .70 .64 .67 .68 .73
 .67 .66 .64 .67 .68 .73
11 GALVANIZED09/13/840306
 .64 .64 .62 .62 .64 .67
 .65 .63 .63 .62 .66 .68
 .60 .63 .61 .66 .67 .73
12 GALVANIZED09/13/840306
 .59 .60 .59 .60 .60 .60
 .64 .64 .66 .64 .66 .61
 .59 .65 .64 .64 .62 .61
15 GALVANIZED09/13/840306
 .65 .61 .63 .66 .63 .63
 .71 .69 .65 .61 .62 .64
```

```
 .71 .70 .70 .69 .68 .68
18 GALVANIZED09/13/840306
 .60 .57 .49 .53 .56 .63
 .64 .62 .63 .63 .62 .64
 .65 .66 .64 .64 .67 .68
19 GALVANIZED09/13/840306
 .71 .70 .72 .71 .76 .75
 .70 .71 .67 .71 .72 .71
 .73 .73 .69 .70 .74 .74
20 GALVANIZED09/13/840306
 .69 .66 .63 .62 .67 .69
 .66 .65 .58 .63 .70 .70
 .70 .65 .65 .65 .69 .73
22 GALVANIZED09/13/840306
 .68 .65 .62 .66 .60 .62
 .68 .70 .66 .68 .69 .67
 .61 .64 .64 .66 .65 .64
23 GALVANIZED09/13/840306
 .66 .63 .64 .65 .68 .66
 .66 .59 .60 .59 .67 .69
 .66 .66 .62 .62 .68 .68
24 GALVANIZED09/13/840305
 .58 .61 .64 .62 .61-9.0
 .61 .58 .63 .52 .56-9.0
 .52 .63 .62 .63 .61-9.0
25 GALVANIZED09/13/840305
 .66 .63 .63 .60 .61-9.0
 .59 .63 .64 .65 .69-9.0
 .60 .62 .65 .63 .62-9.0
26 GALVANIZED09/13/840306
 .69 .69 .70 .69 .69 .66
 .64 .67 .70 .64 .66 .62
 .68 .67 .69 .67 .68 .58
32 GALVANIZED09/13/840306
 .59 .59 .65 .61 .65 .61
 .59 .57 .58 .58 .54 .51
 .71 .69 .68 .64 .67 .71
33 GALVANIZED09/13/840306
 .56 .56 .59 .53 .48 .48
 .54 .61 .54 .54 .57 .54
 .65 .59 .58 .58 .57 .60
34 GALVANIZED09/13/840306
 .47 .51 .47 .45 .48 .53
 .45 .47 .47 .45 .46 .46
 .49 .45 .43 .43 .46 .48
35 GALVANIZED09/13/840306
 .60 .63 .63 .62 .66 .68
 .47 .49 .50 .54 .58 .56
 .48 .43 .44 .49 .56 .58
36 GALVANIZED09/13/840306
 .68 .70 .70 .70 .67 .62
```

```
 .53 .55 .55 .59 .62 .63
 .54 .52 .57 .63 .65 .67
 1 GALVANIZED10/02/850506 59.2
-9.0-9.0 .52 .45 .36-9.0
-9.0 .53 .43 .43 .29 .37
-9.0 .53 .42 .41 .36 .32
 .57 .51 .47 .41 .36 .33
 .56 .53 .53 .48 .34 .30
 2 GALVANIZED10/03/850506 44.7
 .56 .58 .55 .60 .62 .60
 .55 .58 .59 .60 .61 .56
 .54 .59 .56 .61 .62 .60
 .56 .57 .57 .58 .59 .60
 .54 .55 .54 .56 .58 .60
 4 GALVANIZED10/04/850506 48.0
 .59 .59 .58 .60 .61 .59
 .57 .58 .56 .58 .60 .56
 .53 .55 .58 .56 .61 .57
 .55 .53 .58 .60 .62 .56
 .52 .54 .57 .60 .61 .55
 6 GALVANIZED10/04/850506 48.9
-9.0 .64 .61 .64 .64 .56
-9.0 .65 .60 .60 .64 .56
-9.0 .61 .60 .59 .62 .56
-9.0 .62 .56 .60 .61 .59
-9.0 .60 .56 .58 .58 .56
 7 GALVANIZED10/14/850506 65.7
-9.0 .69 .70 .69 .68 .68
-9.0 .67 .69 .71 .71 .65
-9.0 .63 .67 .68 .60 .66
-9.0 .64 .64 .66 .55 .69
-9.0 .61 .68 .66 .67 .68
 8 GALVANIZED10/02/850506 47.7
 .55 .58 .61 .61 .59 .54
 .52 .55 .59 .62 .54 .55
 .53 .57 .55 .55 .56 .57
 .57 .56 .55 .54 .56 .56
 .57 .56 .55 .55 .57 .56
 9 GALVANIZED10/03/850506 48.6
-9.0 .67 .65 .65 .66 .64
 .66 .66 .65 .63 .68 .61
 .63 .66 .62 .62 .65 .58
 .64 .64 .62 .64 .63 .64
 .62 .62 .64 .64 .63 .65
11 GALVANIZED10/04/850506 47.2
-9.0 .62 .59 .63 .64 .60
-9.0 .61 .59 .63 .62 .59
-9.0 .58 .58 .59 .63 .59
-9.0 .62 .60 .60 .64 .58
-9.0 .57 .59 .62 .63 .59
12 GALVANIZED10/04/850506 46.5
```

```
 .56 .52 .57 .58 .56 .53
 .60 .53 .58 .58 .58 .54
 .56 .55 .57 .55 .58 .54
 .57 .56 .58 .55 .54 .55
 .50 .56 .57 .54 .54 .54
15 GALVANIZED10/02/850506 45.8
 .55 .56 .61 .56 .53 .44
 .55 .58 .58 .54 .51 .45
 .59 .57 .55 .53 .52 .44
 .61 .60 .55 .51 .52 .52
 .60 .61 .56 .51 .53 .52
18 GALVANIZED10/04/850506 59.3
 .60 .60 .60 .64 .64 .63
 .60 .60 .60 .62 .59 .63
 .57 .60 .58 .59 .61 .62
 .55 .56 .53 .55 .56 .59
 .54 .53 .43 .48 .54 .57
19 GALVANIZED10/04/850506 59.8
 .48 .54 .52 .55 .60 .57
 .51 .55 .51 .54 .58 .56
 .53 .56 .50 .56 .59 .57
 .57 .54 .54 .56 .57 .57
 .53 .54 .58 .57 .60 .55
20 GALVANIZED10/03/850506 67.0
-9.0 .54 .59 .59 .59 .52
-9.0 .54 .56 .51 .56 .59
-9.0 .51 .48 .53 .57 .60
-9.0 .54 .52 .55 .55 .60
-9.0-9.0 .57 .54 .59 .58
22 GALVANIZED10/02/850506 44.1
 .62 .66 .66 .68 .62 .56
 .65 .68 .67 .68 .65 .57
 .65 .66 .65 .67 .67 .61
 .63 .63 .59 .65 .65 .60
 .63 .62 .56 .57 .55 .54
23 GALVANIZED10/02/850506 62.0
 .48 .55 .49 .54 .56 .52
 .52 .51 .47 .49 .55 .55
 .55 .49 .46 .50 .54 .56
 .56 .52 .54 .53 .56 .61
 .55 .54 .55 .56 .55 .54
24 GALVANIZED10/03/850506 54.5
-9.0 .49 .47 .49 .48-9.0
-9.0 .50 .49 .47 .48-9.0
-9.0 .46 .47 .46 .47-9.0
 .46 .43 .50 .52 .55-9.0
 .46 .45 .54 .53 .48-9.0
25 GALVANIZED10/03/850506 57.0
 .48 .52 .53 .52 .48-9.0
 .48 .51 .53 .55 .55-9.0
 .50 .52 .53 .57 .55-9.0
```

```
 .49 .53 .56 .57 .55-9.0                     .00
 .55 .57 .57 .55 .58-9.0
26 GALVANIZED10/03/850506 66.8
-9.0 .50 .49 .50 .48-9.0
 .49 .49 .49 .47 .48-9.0
 .46 .48 .49 .47 .49-9.0
 .47 .48 .49 .50 .48-9.0
 .46 .48 .51 .51 .48-9.0
30 GALVANIZED04/17/870506 55.8
-9.0-9.0 .39 .56 .40 .55
-9.0-9.0 .53 .51 .57 .50
-9.0-9.0 .57 .35 .58 .57
-9.0-9.0 .52 .40 .54 .51
-9.0-9.0 .55 .54 .59 .59
31 GALVANIZED04/17/870506 55.5
 .58 .62 .55 .62 .61 .57
 .55 .62 .57 .61 .59 .56
 .60 .61 .60 .64 .58 .60
 .59 .57 .57 .61 .66 .64
 .60 .59 .57 .63 .64 .64
32 GALVANIZED04/17/870506 55.3
 .50 .49 .51 .52 .52-.26
 .43 .43 .43 .43 .41-.27
 .49 .42 .42 .44 .40 .39
 .58 .54 .52 .49 .43 .46
 .59 .58 .60 .58 .55 .45
33 GALVANIZED04/17/870506 55.1
 .50 .50 .51 .48 .41 .37
 .41 .45 .44 .41 .35 .31
 .41 .46 .40 .38 .41 .36
 .46 .48 .46 .44 .46 .43
 .53 .49 .47 .50 .50 .53
34 GALVANIZED04/17/870506 54.9
 .44 .44 .42 .43 .44 .48
 .39 .41 .40 .42 .40 .40
 .35 .35 .33 .37 .34 .37
 .40 .36 .34 .36 .37 .41
 .49 .44 .39 .38 .42 .51
35 GALVANIZED04/17/870506 56.6
 .54 .54 .55 .56 .57 .58
 .47 .49 .49 .51 .53 .54
 .41 .44 .43 .46 .48 .49
 .44 .42 .43 .47 .50 .53
 .52 .46 .43 .45 .51 .53
36 GALVANIZED04/17/870506 56.6
 .54 .55 .54 .54 .53 .51
 .51 .53 .52 .53 .52 .51
 .45 .46 .46 .49 .52 .54
 .46 .46 .50 .55 .58 .59
 .47 .47 .53 .57 .57 .57
37 GALVANIZED00/00/000101 32.2
```

Top Mat Readings

```
1 EPOXY      10/14/850000 57.4
.00
2 EPOXY      10/15/850506 60.0
.45 .43 .44 .43 .40 .36
.45 .44 .44 .43 .42 .39
.48 .43 .44 .43 .45 .40
.46 .46 .45 .42 .42 .42
-9. .50 .51 .46 .44 .41
3 EPOXY      10/16/850506 46.0
.58 .60 .54 .55 .56 .55
.54 .58 .55 .51 .55 .55
.52 .56 .54 .50 .54 .55
.59 .57 .53 .52 .55 .55
-9. .55 .55 .54 .55 .54
4 EPOXY      10/22/850506 53.9
.54 .55 .50 .51 .53 .58
.52 .48 .44 .49 .48 .58
.47 .46 .47 .50 .49 .56
.45 .48 .47 .48 .52 .60
.52 .56 .54 .52 .57 -9.
5 EPOXY      10/22/850506 48.9
.59 -9. .60 -9. .61 .60
.59 .61 .60 .62 .61 .60
.58 .59 .59 .61 .59 .60
.57 .57 .59 .60 .58 .58
.55 .58 .56 .59 .56 .57
6 EPOXY      10/28/850506 46.9
.56 .54 .54 .54 .56 .54
.58 .55 .55 .55 .57 .56
.59 .57 .57 .57 .57 .56
.59 .58 .58 .58 .57 .56
.59 .60 .59 .58 .57 .55
7 EPOXY      10/30/850506 38.4
.45 .53 .49 .48 .46 .42
.52 .53 .40 .41 .44 .41
.49 .52 .44 .39 .41 .45
.44 .53 .43 .44 .47 .48
.38 .50 .50 .50 .49 .52
8 EPOXY      10/30/850506 38.4
.60 .58 .56 .56 .58 .57
.59 .55 .56 .56 .55 .57
.58 .56 .58 .57 .55 .58
.58 .55 .58 .58 .58 .61
.57 .58 .58 .58 .61 .58
9 EPOXY      10/14/850000 60.1
.00
10 EPOXY     10/15/850506 60.5
.64 .61 .56 .55 .58 .63
.66 .61 .57 .56 .58 .60
.63 .63 .60 .59 .57 .60
.62 .64 .61 .61 .63 .64
.63 .65 .62 .63 .65 .62
11 EPOXY     10/16/850506 46.3
-9. .64 .64 .61 .61 .62
-9. .66 .64 .62 .64 .65
-9. .64 .65 .63 .63 .65
-9. .64 .63 .63 .67 .60
-9. .59 .66 .65 .63 -9.
12 EPOXY     10/22/850506 49.5
-9. .44 .44 .42 .43 .42
.43 .45 .43 .42 .41 .40
.45 .45 .42 .43 .42 .42
.44 .44 .44 .44 .43 .45
.42 .45 .43 .43 .44 .46
13 EPOXY     10/28/850506 47.1
.58 .56 .56 .58 .64 .60
.58 .53 .54 .58 .62 .61
.61 .52 .60 .56 .59 .58
.62 .59 .57 .55 .60 .60
.62 .62 .55 .53 .62 .62
14 EPOXY     10/29/850506 39.3
.45 .47 .46 .46 .44 .43
.44 .44 .45 .44 .44 .45
.45 .42 .44 .44 .47 .52
.47 .45 .44 .45 .52 .51
.44 .47 .49 .50 .54 .51
15 EPOXY     10/29/850506 47.1
-9. .49 .50 .48 .48 -9.
-9. .47 .46 .42 .47 -9.
-9. .45 .42 .33 .42 -9.
-9. .51 .47 .45 .40 -9.
-9. .52 .48 .47 .42 -9.
16 EPOXY     10/30/850506 41.9
.53 .56 .57 .56 .54 .52
.53 .54 .56 .55 .50 .53
.55 .56 .56 .56 .50 .52
.53 .53 .53 .53 .55 .55
.52 .53 .57 .53 .52 .55
17 EPOXY     10/16/850506 45.9
.50 .51 .52 .51 .51 .56
.46 .41 .41 .49 .55 .59
.46 .43 .43 .47 .51 .57
.53 .46 .46 .51 .55 .59
.53 .51 .51 .55 .52 .57
18 EPOXY     10/16/850506 45.4
.54 .55 .55 .54 .54 .54
.54 .54 .54 .54 .54 .52
.54 .55 .54 .52 .53 .53
```

Top Mat Readings

```
 .54 .54 .54 .53 .54 .52
 -9. .54 .54 .54 .55 .54
19 EPOXY      10/16/850506 51.2
 .63 .63 .59 .57 .58 .51
 .63 .58 .57 .57 .55 .55
 .59 .56 .57 .54 .54 .56
 .61 .58 .59 .57 .61 .59
 .62 .62 .60 .61 .64 .64
20 EPOXY      10/22/850506 49.2
 .60 .61 .60 .61 .64 .62
 .61 .63 .60 .64 .66 .62
 .60 .65 .61 .63 .67 .65
 .61 .64 .63 .64 .65 .63
 .59 .63 .62 .62 .63 .62
21 EPOXY      10/28/850506 47.0
 .57 .58 .58 .58 .60 .58
 .58 .60 .56 .58 .60 .59
 .58 .57 .58 .60 .60 .59
 .58 .59 .59 .60 .60 .60
 .57 .60 .59 .60 .63 .60
22 EPOXY      10/29/850506 40.7
 .46 .44 .46 .47 .45 .47
 .47 .44 .48 .45 .43 .46
 .47 .47 .49 .48 .47 .46
 .46 .48 .49 .48 .48 .44
 .45 .47 .45 .46 .45 .43
23 EPOXY      10/29/850506 48.4
 .55 .57 .62 .58 .62 .60
 .59 .55 .55 .61 .60 .60
 .59 .59 .58 .58 .58 .59
 .60 .62 .58 .58 .57 .59
 .59 .63 .65 .59 .59 .61
24 EPOXY      10/30/850506 42.5
 .51 .51 .52 .50 .51 .47
 .52 .52 .51 .49 .49 .49
 .51 .51 .51 .50 .49 .48
 .52 .51 .50 .49 .49 .49
 .52 .52 .51 .49 .49 .49
25 EPOXY      10/15/850506 58.3
 .53 .52 .52 .51 .55 .55
 .52 .52 .51 .53 .54 .57
 .54 .51 .53 .54 .52 .57
 .55 .51 .53 .55 .55 .57
 .57 .55 .55 .56 .58 .57
26 EPOXY      10/16/850506 42.1
 .56 .61 .58 .57 .54 .56
 .58 .61 .50 .54 .49 .58
 .60 .58 .52 .48 .53 .58
 .59 .62 .56 .59 .60 .62
```

```
 .52 .61 .60 .61 .62 .60
27 EPOXY      10/18/850506 54.2
 .56 .59 .59 .57 .57 -9.
 .53 .59 .57 .56 .62 .63
 .54 .59 .57 .53 .61 .58
 .61 .60 .59 .58 .64 -9.
 .62 .66 .62 .63 .64 -9.
28 EPOXY      10/22/850506 49.0
 .64 .67 .69 .68 .67 -9.
 .68 .68 .68 .68 .66 .65
 .68 .69 .68 .66 .66 .64
 -9. .69 .69 .66 .66 .65
 -9. .68 .69 .66 .66 .64
29 EPOXY      10/28/850506 47.0
 -9. .57 .61 .59 .57 .49
 -9. .60 .54 .55 .62 .57
 -9. .57 .51 .52 .61 .60
 -9. .59 .51 .54 .62 .57
 -9. .59 .57 .57 .59 .60
30 EPOXY      10/29/850506 40.7
 .58 .56 .55 .47 .48 .46
 .59 .52 .55 .45 .49 .52
 .57 .50 .51 .43 .47 .49
 .55 .47 .48 .46 .46 .49
 .55 .49 .48 .49 .50 .53
31 EPOXY      10/30/850506 39.5
 .47 .50 .50 .49 .48 .46
 .46 .51 .50 .50 .47 .45
 .47 .51 .49 .50 .48 .44
 .46 .51 .49 .48 .47 .45
 .47 .48 .47 .45 .46 .44
32 EPOXY      10/31/850506 44.6
 .53 .56 .56 .57 .56 .51
 .52 .55 .54 .55 .51 .48
 .52 .52 .54 .54 .51 .48
 .51 .50 .51 .51 .52 .49
 .50 .51 .52 .50 .51 .50
33 EPOXY      10/31/850506 43.9
 .50 .49 .50 .50 .49 .44
 .43 .43 .45 .44 .46 .45
 .45 .43 .45 .43 .43 .43
 .46 .45 .46 .46 .43 .46
 .42 .46 .48 .48 .45 .42
34 EPOXY      10/31/850506 48.5
 -9. -9. .67 .65 .63 -9.
 -9. .64 .65 .63 .66 -9.
 -9. .61 .63 .59 .62 -9.
 -9. .61 .58 .57 .62 -9.
 -9. .61 .62 .58 .60 -9.
```

Top Mat Readings

```
35 EPOXY     10/31/850506 42.4
 .32 .34 .33 .32 .28 .30
 .33 .31 .30 .30 .28 .30
 .33 .31 .30 .29 .27 .29
 .32 .30 .28 .29 .29 .30
 .32 .30 .29 .30 .30 .31
36 EPOXY     10/30/850506 44.0
 -9. .57 .56 .55 .56 -9.
 -9. .53 .50 .49 .54 -9.
 -9. .53 .47 .49 .50 -9.
 -9. .52 .49 .52 .54 -9.
 -9. .55 .55 .53 .55 -9.
37 EPOXY     11/01/850506 58.0
 .65 .67 .61 .58 .54 .50
 .63 .61 .58 .57 .51 .54
 .63 .62 .59 .59 .57 .55
 .62 .62 .61 .63 .61 .59
 .63 .66 .68 .66 .63 -9
38 EPOXY     10/30/850506 43.0
 .52 .51 .55 .54 .52 .50
 .49 .53 .54 .52 .51 .51
 .49 .54 .53 .53 .54 .50
 .48 .50 .52 .52 .51 .50
 .47 .50 .51 .51 .52 .51
```

Bottom Mat Readings

```
1 EPOXY      10/14/850000 57.4
.00
2 EPOXY      10/15/850506 60.0
.40 .42 .40 .39 .35 .36
.41 .39 .29 .24 .31 .36
.41 .40 .28 .25 .25 .37
.42 .41 .40 .38 .28 .36
.47 .43 .42 .39 .38 .37
3 EPOXY      10/16/850506 46.0
.50 .49 .47 .45 .44 .50
.42 .47 .45 .43 .43 .46
.38 .44 .45 .42 .43 .43
.47 .47 .44 .46 .43 .44
.52 .49 .49 .48 .47 .48
4 EPOXY      10/22/850506 53.9
.49 .48 .48 .49 .46 .51
.45 .42 .42 .37 .44 .51
.40 .37 .35 .30 .45 .49
.42 .40 .40 .39 .42 .55
.43 .48 .46 .45 .48 .55
5 EPOXY      10/22/850506 48.9
.51 .46 .47 .49 .47 .50
```

Bottom Mat Readings

```
.47 .46 .47 .48 .46 .48
.45 .46 .44 .53 .46 .46
.45 .45 .47 .43 .45 .46
.44 .44 .44 .45 .44 .46
6 EPOXY      10/28/850506 46.9
.50 .46 .47 .46 .46 .47
.50 .47 .47 .47 .47 .46
.50 .49 .48 .48 .48 .47
.52 .49 .49 .48 .47 .50
.54 .50 .49 .49 .48 .50
7 EPOXY      10/30/850506 38.4
.62 .59 .53 .50 .50 .50
.64 .56 .49 .46 .49 .51
.60 .55 .50 .46 .51 .55
.61 .55 .53 .53 .55 .59
.59 .55 .57 .60 .58 .58
8 EPOXY      10/30/850506 38.4
.62 .59 .57 .57 .57 .58
.60 .57 .56 .57 .56 .58
.60 .58 .55 .57 .56 .58
.59 .58 .55 .58 .58 .60
.62 .58 .60 .58 .60 .64
9 EPOXY      10/14/850000 60.1
.00
10 EPOXY     10/15/850506 60.5
.61 .55 .50 .47 .52 .53
.63 .55 .51 .50 .53 .52
.60 .55 .38 .44 .54 .54
.57 .55 .55 .53 .56 .57
.59 .55 .55 .56 .58 .59
11 EPOXY     10/16/850506 46.3
-9. .61 .60 .60 .60 .58
-9. .60 .60 .47 .54 .61
-9. .60 .60 .47 .62 .61
-9. .60 .60 .49 .63 .62
-9. .60 .60 .62 .62 .62
12 EPOXY     10/22/850506 49.5
.63 .58 .57 .56 .55 .52
.64 .57 .56 .56 .55 .55
.62 .57 .57 .56 .56 .55
.58 .57 .57 .57 .56 .55
.58 .58 .57 .57 .57 .56
13 EPOXY     10/28/850506 47.1
.50 .46 .42 .44 .49 .50
.47 .45 .44 .47 .50 .52
.49 .43 .46 .45 .50 .51
.52 .45 .46 .46 .50 .51
.51 .48 .45 .45 .49 .51
14 EPOXY     10/29/850506 39.3
```

Bottom Mat Readings

```
 .53 .49 .48 .47 .46 .47
 .50 .45 .44 .45 .44 .48
 .46 .45 .34 .42 .46 .50
 .47 .47 .46 .49 .52 .53
 .48 .49 .48 .51 .57 .55
15 EPOXY      10/29/850506 47.1
 -9. .52 .53 .53 .53 -9.
 -9. .51 .47 .45 .52 -9.
 -9. .50 .48 .40 .46 -9.
 -9. .51 .51 .49 .44 -9.
 -9. .54 .52 .53 .43 -9.
16 EPOXY      10/30/850506 41.9
 .61 .53 .53 .52 .52 .52
 .54 .53 .53 .52 .52 .53
 .53 .53 .52 .52 .52 .52
 .54 .52 .52 .52 .52 .52
 .57 .53 .53 .52 .52 .54
17 EPOXY      10/16/850506 45.9
 .47 .43 .43 .46 .51 .45
 .47 .44 .42 .47 .52 .51
 .46 .43 .40 .48 .50 .57
 .47 .46 .44 .47 .51 .54
 .48 .50 .46 .48 .52 -9.
18 EPOXY      10/16/850506 45.4
 .62 .57 .58 .57 .59 .59
 .57 .58 .58 .58 .59 .59
 .57 .56 .44 .57 .59 .59
 .57 .57 .58 .58 .58 .57
 .57 .56 .58 .58 .58 .57
19 EPOXY      10/16/850506 51.2
 .61 .56 .54 .53 .54 .50
 .61 .54 .52 .53 .54 .51
 .57 .54 .52 .53 .54 .51
 .58 .54 .53 .52 .54 .55
 .61 .56 .54 .55 .57 .61
20 EPOXY      10/22/850506 49.2
 .50 .48 .49 .50 .50 .52
 .49 .49 .49 .50 .50 .52
 .49 .43 .44 .51 .51 .51
 .49 .45 .48 .43 .50 .50
 .50 .49 .49 .50 .50 .50
21 EPOXY      10/28/850506 47.0
 .56 .55 .54 .54 .56 .57
 .56 .56 .55 .53 .55 .56
 .55 .56 .53 .54 .56 .57
 .56 .55 .56 .56 .57 .59
 .60 .57 .57 .57 .59 .59
22 EPOXY      10/29/850506 40.7
 .52 .48 .48 .49 .50 .50
```

```
 .50 .48 .47 .48 .48 .48
 .49 .45 .37 .38 .45 .50
 .51 .48 .39 .48 .43 .47
 .55 .49 .49 .48 .47 .46
23 EPOXY      10/29/850506 48.4
 .46 .47 .46 .46 .47 .48
 .49 .45 .44 .44 .44 .46
 .44 .44 .46 .43 .44 .46
 .47 .46 .47 .44 .46 .46
 .52 .47 .45 .46 .49 .51
24 EPOXY      10/30/850506 42.5
 .46 .39 .38 .38 .39 .39
 .43 .38 .38 .39 .38 .38
 .43 .39 .38 .36 .38 .37
 .41 .39 .38 .37 .37 .35
 .41 .40 .38 .37 .37 .35
25 EPOXY      10/15/850506 58.3
 .79 .50 .48 .50 .48 .51
 .49 .44 .36 .39 .49 .50
 .50 .39 .36 .37 .50 .50
 .50 .49 .30 .39 .51 .50
 .52 .50 .50 .51 .51 .53
26 EPOXY      10/16/850506 42.1
 .50 .45 .42 .42 .43 .45
 .49 .44 .39 .38 .43 .48
 .48 .44 .36 .28 .45 .48
 .49 .45 .42 .43 .49 .51
 .45 .48 .48 .49 .52 .51
27 EPOXY      10/18/850506 54.2
 .51 .55 .53 .50 .55 .58
 .52 .53 .54 .48 .55 .58
 .55 .52 .58 .50 .57 .58
 .60 .56 .53 .55 .56 .57
 .61 .57 .55 .57 .57 .61
28 EPOXY      10/22/850506 49.0
 -9. .61 .61 .62 .61 .61
 .62 .61 .61 .60 .60 .61
 .62 .61 .61 .61 .61 .60
 .64 .62 .61 .61 .59 .60
 -9. .61 .62 .61 .60 .57
29 EPOXY      10/28/850506 47.0
 -9. .60 .64 .61 .61 .56
 -9. .63 .58 .59 .66 .62
 -9. .61 .55 .58 .67 .65
 -9. .62 .55 .56 .66 .60
 -9. .61 .61 .62 .64 .65
30 EPOXY      10/29/850506 40.7
 .61 .51 .49 .47 .47 .50
 .59 .49 .47 .45 .45 .48
```

Bottom Mat Readings

```
 .58 .47 .44 .40 .43 .48
 .50 .44 .42 .50 .43 .45
 .49 .44 .43 .45 .45 .47
31 EPOXY     10/30/850506 39.5
 .55 .51 .49 .49 .50 .53
 .52 .48 .49 .41 .49 .52
 .52 .49 .48 .35 .49 .52
 .53 .50 .49 .49 .49 .50
 .54 .50 .49 .48 .48 .49
32 EPOXY     10/31/850506 44.6
 .47 .44 .43 .42 .41 .42
 .46 .43 .42 .41 .41 .42
 .46 .43 .42 .42 .42 .42
 .47 .43 .42 .42 .42 .43
 .51 .44 .43 .43 .43 .44
33 EPOXY     10/31/850506 43.9
 .55 .49 .47 .48 .49 .43
 .55 .49 .47 .48 .49 .43
 .53 .45 .43 .43 .44 .45
 .51 .44 .45 .44 .45 .48
 .50 .46 .47 .48 .49 .50
34 EPOXY     10/31/850506 48.5
 -9. .52 .52 .54 .52 -9.
 -9. .52 .52 .53 .52 -9.
 -9. .51 .47 .51 .51 -9.
 -9. .50 .50 .50 .50 -9.
 -9. .50 .49 .49 .49 -9.
35 EPOXY     10/31/850506 42.4
 .55 .53 .55 .52 .50 .48
 .54 .53 .60 .49 .49 .51
 .53 .51 .47 .42 .43 .52
 .53 .50 .53 .53 .49 .50
 .54 .49 .51 .50 .49 .50
36 EPOXY     10/30/850506 44.0
 .45 .44 .42 .43 .43 -9.
 .45 .42 .41 .41 .42 -9.
 .45 .41 .40 .41 .41 -9.
 -9. .42 .40 .41 .42 -9.
 -9. .43 .42 .41 .41 -9.
37 EPOXY     11/01/850506 58.0
 .51 .48 .44 .38 .36 .36
 .47 .48 .32 .39 .37 .36
 .45 .44 .45 .40 .38 .42
 .46 .46 .47 .45 .43 .46
 .48 .48 .47 .47 .47 .49
38 EPOXY     10/30/850506 43.0
 .55 .55 .56 .56 .56 .57
 .55 .55 .56 .57 .57 .57
 .55 .56 .56 .57 .57 .57
```

```
.57 .55 .56 .56 .57 .59
.60 .55 .55 .56 .57 .60
```

Appendix F

Appendix F Chloride Ion Concentrations for Galvanized Field Exposure Specimens.

SALT CONTENT DATA [A = UNCOATED, B = GALVANIZED, C = UNCOATED, SPLICED]

BLOCK NO.	CORE NO.	DATE	% NaCl 1	% NaCl 2	% NaCl 3	% NaCl 4	Cl(lb/cy) 1	Cl(lb/cy) 2	Cl(lb/cy) 3	Cl(lb/cy) 4
	DEPTH (INCHES)		1.25	2.0	2.75	6.0	1.25	2.0	2.75	6.0
1	1	5-76	0.4311	0.1680	0.1095		10.14	3.95	2.57	
	A1	12-81	0.5410	0.5040	0.3000	0.2850	12.72	11.87	7.05	6.71
	B1	12-81	0.3440	0.1970	0.0590		8.09	4.64	1.39	
	2	5-76	0.2484	0.0876	0.0292		5.84	2.06	0.69	
	A2	12-81	0.3510	0.2410	0.1170		8.26	5.67	2.75	
	B2	12-81	0.2560	0.1460	0.0510		6.02	3.44	1.20	
2	1	5-76	0.2338	0.3361	0.2119		5.50	7.90	4.98	
	A1	12-81	0.4530	0.4460	0.4900		10.66	10.49	11.52	
	B1	12-81	0.5120	0.4530	0.4900		12.04	10.66	11.52	
	2	5-76	0.1827	0.1680	0.1387		4.30	3.95	3.26	
	A2	12-81	0.4970	0.4310	0.3220	0.3140	11.70	10.14	7.57	7.40
	B2	12-81	0.5040	0.4460	0.4970		11.87	10.49	11.70	
3	1	5-76	0.3288	0.3068	0.3799		7.73	7.21	8.93	
	A1	12-81	0.4610	0.4610	0.3440		10.84	10.84	8.09	
	B1	12-81	0.4970	0.4680	0.3290	0.3440	11.70	11.01	7.74	8.09
	2	5-76	0.6650	0.6950	0.2410		15.64	16.35	5.67	
	A2	12-81	0.5190	0.4830	0.4970		12.21	11.35	11.70	
	B2	12-81	0.3220	0.4830	0.3440		7.57	11.35	8.09	
4	1	5-76	0.6510	0.6220	0.3360		15.31	14.63	7.90	
	A1	12-81	0.5040	0.4610	0.4460		11.87	10.84	10.49	
	81	12-81	0.7020	0.5040	0.4750		16.51	11.87	11.17	
	2	5-76	0.3360	0.4610	0.5340		7.90	10.84	12.56	
	A2	12-81	0.6510	0.4970	0.4900		15.31	11.70	11.52	
	B2	12-81	0.5190	0.4900	0.5040	0.2120	12.21	11.52	11.87	4.99
5	1	5-76	0.5920	0.4680	0.3950		13.92	11.01	9.29	
	A1	12-81	0.3000	0.2850	0.2710	0.1390	7.05	6.71	6.36	3.27
	B1	12-81	0.4530	0.0590	0.3440		10.66	1.39	8.09	
	2	5-76	0.6220	0.4530	0.2630		14.63	10.65	6.19	
	A2	12-81	0.4390	0.3510	0.2710		10.33	8.26	6.36	
	B2	12-81	0.4900	0.4530	0.3290		11.52	10.66	7.74	
6	1	5-76	0.6650	0.4460	0.4170		15.64	10.49	9.81	
	A1	12-81	0.4610	0.4830	0.4390		10.84	11.35	10.33	
	B1	12-81	0.4750	0.4610	0.3580		11.17	10.84	8.43	
	2	5-76	0.6730	0.4390	0.3880		15.83	10.33	9.13	
	A2	12-81	0.4900	0.4680	0.4680	0.3290	11.52	11.01	11.01	7.74
	82	12-81	0.5260	0.4610	0.3070		12.37	10.84	7.22	
7	1	5-76	0.6650	0.4310	0.4460		15.64	10.14	10.49	
	A1	12-81	0.4830	0.4170	0.4240		11.35	9.80	9.98	
	B1	12-81	0.4750	0.4750	0.4530	0.3510	11.17	11.17	10.66	8.26
	2	5-76	0.4460	0.4240	0.3580		10.49	9.97	8.42	
	A2	12-81	0.6360	0.3950	0.4610		14.96	9.29	10.84	
	B2	12-81	0.4530	0.4530	0.3660		10.66	10.66	7.91	
8	1	5-76	0.4310	0.4310	0.1680		10.14	10.14	3.95	
	A1	12-81	0.4900	0.4750	0.4530		11.52	11.17	10.66	
	B1	12-81	0.4900	0.4900	0.3290		11.52	11.52	7.74	
	2	5-76	0.7020	0.4310	0.4530		16.51	10.14	10.65	
	A2	12-81	0.4610	0.4610	0.3290		10.84	10.84	7.74	
	B2	12-81	0.4900	0.4610	0.4610	0.3000	11.52	10.84	10.84	7.05
9	1	5-76	0.6360	0.6290	0.4750		14.96	14.79	11.17	
	A1	12-81	0.4900	0.4530	0.4530	0.3070	11.52	10.66	10.66	7.22
	B1	12-81	0.4900	0.4970	0.4970		11.52	11.70	11.70	
	2	5-76	0.3880	0.3510	0.1970		9.12	8.26	4.63	
	A2	12-81	0.4610	0.4460	0.3440		10.84	10.49	8.09	
	B2	12-81	0.5040	0.4680	0.4610		11.87	11.01	10.84	
10	1	5-76	0.2270	0.3800	0.3950		5.34	8.94	9.29	
	A1	12-81	0.5120	0.4530	0.3220		12.04	10.66	7.57	
	81	12-81	0.4680	0.4750	0.4750		11.01	11.17	11.17	
	2	5-76	0.6510	0.4750	0.3730		15.31	11.17	8.77	
	A2	12-81	0.5190	0.3220	0.4460	0.3220	12.21	7.57	10.49	7.57
	B2	12-81	0.4680	0.5260	0.4680		11.01	12.37	11.01	
11	1	5-76	0.5191	0.5847	0.4380		12.21	13.75	11.36	

Appendix F Chloride Ion Concentrations for Galvanized Field Exposure Specimens.

SALT CONTENT DATA [A = UNCOATED, B = GALVANIZED, C = UNCOATED, SPLICED]

BLOCK NO.	CORE NO.	DATE	% NaCl 1	% NaCl 2	% NaCl 3	% NaCl 4	Cl(lb/cy) 1	Cl(lb/cy) 2	Cl(lb/cy) 3	Cl(lb/cy) 4
	DEPTH (INCHES)		1.25	2.0	2.75	6.0	1.25	2.0	2.75	6.0
	A1	12-81	0.3360	0.3000	0.3000		7.91	7.05	7.05	
	B1	12-81	0.4680	0.4390	0.4020	0.3440	11.01	10.33	9.46	8.09
	2	5-76	0.5918	0.4604	0.3216		13.91	10.83	7.56	
	A2	12-81	0.5120	0.3290	0.4100		12.04	7.74	9.63	
	B2	12-81	0.4970	0.4530	0.4610		11.70	10.66	10.84	
12	1	5-76	0.6580	0.6795	0.4237		15.48	15.98	9.96	
	A1	12-81	0.6510	0.6800	0.6650		15.31	15.99	15.64	
	B1	12-81	0.6800	0.6950	0.6650		15.99	16.34	15.64	
	2	5-76	0.9070	0.5628	0.3581		21.33	13.23	8.42	
	A2	12-81	0.6360	0.4830	0.3070		14.96	11.35	7.22	
	B2	12-81	0.7240	0.6290	0.5190	0.4830	17.03	14.79	12.21	11.35
13	1	5-76	0.5553	0.4680	0.2850		13.06	11.00	6.70	
	A1	12-81	0.5120	0.4460	0.3360	0.0000	12.04	10.49	7.91	0.00
	B1	12-81	0.4310	0.3000	0.2780		10.14	7.05	6.54	
	2	5-76	0.6651	0.5411	0.3436		15.64	12.72	8.08	
	A2	12-81	0.5120	0.4610	0.4170		12.04	10.84	9.80	
	B2	12-81	0.4830	0.3140	0.2410		11.35	7.40	5.67	
14	1	5-76	0.7891	0.6724	0.6434		18.55	15.81	15.13	
	A1	12-81	0.4750	0.4750	0.4750		11.17	11.17	11.17	
	B1	12-81	0.6650	0.4750	0.4460		15.64	11.17	10.49	
	2	5-76	0.7239	0.4825	0.4900		17.02	11.34	11.52	
	A2	12-81	0.6000	0.4900	0.4680	0.4610	14.11	11.52	11.01	10.84
	B2	12-81	0.5120	0.4900	0.4680		12.04	11.52	11.01	
15	1	5-76	0.6137		0.4020		14.43		9.45	
	A1	12-81	0.4610	0.4390	0.3360		10.84	10.33	7.91	
	B1	12-81	0.4750	0.3360	0.3220	0.0950	11.17	7.91	7.57	2.24
	2	5-76	0.4605	0.3216	0.1315		10.83	7.56	3.09	
	A2	12-81	0.5120	0.4830	0.4390		12.04	11.35	10.33	
	B2	12-81	0.4680	0.3360	0.2560		11.01	7.91	6.02	
16	1	5-76	0.7015	0.4895	0.5120		16.49	11.51	12.04	
	A1	12-81	0.4460	0.4750	0.4830		10.49	11.17	11.35	
	81	12-81	0.6360	0.4900	0.4900		14.96	11.52	11.52	
	2	5-76	0.7235	0.4748	0.3580		17.01	11.16	8.42	
	A2	12-81	0.6870	0.6220	0.4970		16.16	14.63	11.70	
	B2	12-81	0.5040	0.5190	0.4610	0.4830	11.87	12.21	10.84	11.35
17	1	5-76	0.6435	0.4095	0.4384		15.13	9.63	10.31	
	A1	12-81	0.4830	0.3580	0.3290	0.3140	11.35	8.43	7.74	7.40
	B1	12-81	0.4680	0.3660	0.3360		11.01	8.60	7.91	
	2	5-76	0.4533	0.4387	0.3363		10.66	10.32	7.91	
	A2	12-81	0.3440	0.3290	0.3440		8.09	7.74	8.09	
	82	12-81	0.7090	0.3580	0.3140		16.68	8.43	7.40	
18	1	5-76	0.3361	0.1826	0.0657		7.90	4.29	1.54	
	A1	12-81	0.2630	0.3220	0.2270		6.19	7.57	5.33	
	B1	12-81	0.4750	0.3000	0.2490		11.17	7.05	5.85	
	2	5-76	0.3654	0.1680	0.0804		8.59	3.95	1.89	
	A2	12-81	0.3070	0.2710	0.1970	0.0150	7.22	6.36	4.64	0.35
	82	12-81	0.3360	0.2930	0.2050		7.91	6.88	4.82	
19	1	5-76	0.5115	0.5334	0.4313		12.03	12.54	10.14	
	A1	12-81	0.4970	0.4900	0.3510		11.70	11.52	8.26	
	81	12-81	0.3580	0.3440	0.2850	0.2710	8.43	8.09	6.71	6.36
	2	5-76	0.4166	0.2704	0.1681		9.80	6.36	3.95	
	A2	12-81	0.5260	0.3360	0.3440		12.37	7.91	8.09	
	82	12-81	0.4970	0.4680	0.4830		11.70	11.01	11.35	
20	1	5-76	0.5044	0.4968	0.3435		11.86	11.68	8.08	
	A1	12-81	0.7020	0.4750	0.4680		16.51	11.17	11.01	
	B1	12-81	0.7240	0.4970	0.3440		17.03	11.70	8.09	
	2	5-76	0.4310	0.4898	0.4240		10.13	11.52	9.97	
	A2	12-81	0.6730	0.4830	0.3440		15.83	11.35	8.09	
	B2	12-81	0.5040	0.3730	0.3220	0.1460	11.87	8.77	7.57	3.44
21	1	5-76	0.6580	0.6440	0.4020		15.48	15.15	9.46	
	A1	12-81	0.4680	0.4750	0.4460	0.2630	11.01	11.17	10.49	6.19
	B1	12-81	0.4970	0.4750	0.3360		11.70	11.17	7.91	

<u>Appendix F</u> Chloride Ion Concentrations for Galvanized Field Exposure Specimens.

SALT CONTENT DATA [A = UNCOATED, 8 = GALVANIZED, C = UNCOATED, SPLICED]

BLOCK NO.	CORE NO.	DATE	% NaCl				Cl(lb/cy)			
			1	2	3	4	1	2	3	4
	DEPTH (INCHES)		1.25	2.0	2.75	6.0	1.25	2.0	2.75	6.0
	2	5-76	0.6360	0.6070	0.4020		14.96	14.28	9.46	
	A2	12-81	0.6580	0.5040	0.4900		15.48	11.87	11.52	
	B2	12-81	0.4310	0.4900	0.3360		10.14	11.52	7.91	
22	1	5-76	0.8920	0.6580	0.4830		20.98	15.48	11.36	
	A1	12-81	0.6440	0.6360	0.4750		15.15	14.96	11.17	
	81	12-81	0.6950	0.5340	0.4970		16.34	12.56	11.70	
	2	5-76	0.9070	0.6730	0.6140		21.33	15.83	14.44	
	A2	12-81	0.6800	0.6440	0.4830	0.3580	15.99	15.15	11.35	8.43
	82	12-81	0.7240	0.7020	0.6440		17.03	16.51	15.15	
23	1	5-76	0.8990	0.6580	0.4610		21.14	15.48	10.84	
	A1	12-81	0.3140	0.3290	0.3660		7.40	7.74	8.60	
	B1	12-81	0.4830	0.4970	0.4830	0.3440	11.35	8.09	11.35	8.09
	2	5-76	0.6730	0.8260	0.4530		15.83	19.43	10.65	
	A2	12-81	0.3360	0.4900	0.4900		7.91	11.52	11.52	
	B2	12-81	0.4460	0.3440	0.3290		10.49	8.09	7.74	
24	1	5-76	0.3220	0.1020	0.2490		7.57	2.40	5.86	
	A1	12-81	0.3290	0.3140	0.3140		7.74	7.40	7.40	
	B1	12-81	0.8340	0.4970	0.4830		19.61	11.70	11.35	
	2	5-76	0.7820	0.6140	0.4390		18.39	14.44	10.32	
	A2	12-81	0.4900	0.3220	0.3220		11.52	7.57	7.57	
	B2	12-81	0.4750	0.4900	0.4680	0.3360	11.17	11.52	11.01	7.91
25	1	5-76	0.4100	0.0440	0.0580		9.64	1.03	1.36	
	A1	12-81	0.3580	0.3360	0.2930	0.5040	8.43	7.91	6.88	11.87
	B1	12-81	0.6870	0.5260	0.4390		16.16	12.37	10.33	
	2	5-76	0.7310	0.4830	0.6650		17.19	11.36	15.64	
	A2	12-81	0.3360	0.3140	0.2270		7.91	7.40	5.33	
	B2	12-81	0.4830	0.4530	0.4680		11.35	10.66	11.01	
26	1	5-76	0.4900	0.4020	0.1320		11.52	9.46	3.10	
	A1	12-81	0.4610	0.4530	0.4460		10.84	10.66	10.49	
	81	12-81	0.4900	0.3360	0.3290		11.52	7.91	7.74	
	2	5-76	0.4390	0.4610	0.1020		10.32	10.84	2.40	
	A2	12-81	0.4970	0.4830	0.4310	0.1970	11.70	11.35	10.14	4.64
	B2	12-81	0.4610	0.4830	0.4460		10.84	11.35	10.49	
27	1	5-76	1.1190	0.6650	0.4310		26.32	15.64	10.14	
	A1	12-81	0.4750	0.2930	0.2780		11.17	6.88	6.54	
	81	12-81	0.4830	0.4610	0.4240	0.4680	11.35	10.84	9.98	11.01
	2	5-76	0.6950	0.6870			16.35	16.16		
	A2	12-81	0.5260	0.3440	0.5630		12.37	8.09	13.24	
	B2	12-81	0.4170	0.3220	0.3220		9.80	7.57	7.57	
28	A1	12-81	0.3220	0.3070	0.2630		7.57	7.22	6.19	
	81	12-81	0.3070	0.3140	0.3290		7.22	7.40	7.74	
	A2	12-81	0.4680	0.3290	0.3290		11.01	7.74	7.74	
	82	12-81	0.3580	0.4680	0.3220	0.3220	8.43	11.01	7.57	7.57
29	A1	12-81	0.4610	0.2780	0.3220	0.3440	10.84	6.54	7.57	8.09
	81	12-81	0.4900	0.4680	0.4530		11.52	11.01	10.66	
	A2	12-81	0.4680	0.4610	0.4680		11.01	10.84	11.01	
	B2	12-81	0.4830	0.3580	0.3440		11.35	8.43	8.09	
30	1	5-76	0.6800	0.6360			15.99	14.96		
	A1	12-81	0.4830	0.5040	0.4610		11.35	11.87	10.84	
	B1	12-81	0.4750	0.4240	0.3440		11.17	9.98	8.09	
	C1	12-81	0.4240	0.5260	0.3000		9.98	12.37	7.05	
	2	5-76	0.8560	0.6140			20.13	14.44		
	A2	12-81	0.3140	0.3220	0.4610	0.4240	7.40	7.57	10.84	9.98
	B2	12-81	0.3360	0.3360	0.3510		7.91	7.91	8.26	
	C2	12-81	0.2490	0.2340	0.2410	0.0070	5.85	5.50	5.67	0.16
	3	5-76	0.8990	0.5340			21.14	12.56		
31	1	5-76	0.4170	0.1320			9.81	3.10		
	A1	12-81	0.2120	0.3070	0.1240		4.99	7.22	2.92	
	B1	12-81	0.1540	0.2340	0.4240	0.3290	3.61	5.50	9.98	7.74
	2	5-76	0.4900	0.2270			11.52	5.34		
	A2	12-81	0.4750	0.2780	0.4830		11.17	6.54	11.35	
	B2	12-81	0.4680	0.2850	0.2490		11.01	6.71	5.85	

SALT CONTENT DATA [A = UNCOATED, B = GALVANIZED, C = UNCOATED, SPLICED]

BLOCK NO.	CORE NO.	DATE	% NaCl 1	% NaCl 2	% NaCl 3	% NaCl 4	Cl(lb/cy) 1	Cl(lb/cy) 2	Cl(lb/cy) 3	Cl(lb/cy) 4
	DEPTH (INCHES)		1.25	2.0	2.75	6.0	1.25	2.0	2.75	6.0
32	1	5-76	0.2120	0.0950			4.99	2.23		
	A1	12-81	0.2780	0.2630	0.2850		6.54	6.19	6.71	
	B1	12-81	0.4310	0.2930	0.1830		10.14	6.88	4.30	
	2	5-76	0.6070	0.1170			14.28	2.75		
	A2	12-81	0.4020	0.2560	0.1540		9.46	6.02	3.61	
	B2	12-81	0.2710	0.1760	0.1970	0.0440	6.36	4.13	4.64	1.03
33	1	5-76	0.1020	0.0220			2.40	0.52		
	A1	12-81	0.3440	0.2630	0.2340	0.1900	8.09	6.19	5.50	4.47
	B1	12-81	0.3220	0.2710	0.1760		7.57	6.36	4.13	
	2	5-76	0.1170	0.0070			2.75	0.16		
	A2	12-81	0.3000	0.2560	0.1540		7.05	6.02	3.61	
	B2	12-81	0.3440	0.2930	0.1610		8.09	6.88	3.78	
34	1	5-76		0.0000				0.00		
	A1	12-81	0.3000	0.2630	0.1460		7.05	6.19	3.44	
	B1	12-81	0.2930	0.1900	0.1390		6.88	4.47	3.27	
	2	5-76	0.0146	0.0365	0.1023		0.34	0.86	2.41	
	A2	12-81	0.4750	0.2780	0.2120	0.0440	11.17	6.54	4.99	1.03
	B2	12-81	0.3440	0.3070	0.1970		8.09	7.22	4.64	
35	1	5-76	0.0511	0.0292	0.0146		1.20	0.69	0.34	
	A1	12-81	0.4100	0.2560	0.2930		9.63	6.02	6.88	
	B1	12-81	0.3290	0.2850	0.1970	0.0220	7.74	6.71	4.64	0.52
	2	5-76	0.0657	0.0438	0.0292		1.54	1.03	0.69	
	A2	12-81	0.4390	0.2710	0.2560		10.33	6.36	6.02	
	B2	12-81	0.2850	0.2410	0.1830		6.71	5.67	4.30	
36	1	5-76	0.0584	0.0292	0.0146		1.37	0.69	0.34	
	A1	12-81	0.4460	0.3070	0.1900		10.49	7.22	4.47	
	B1	12-81	0.4310	0.3220	0.1830		10.14	7.57	4.30	
	2	5-76	0.0511		0.0146		1.20		0.34	
	A2	12-81	0.4610	0.3140	0.2340		10.84	7.40	5.50	
	B2	12-81	0.4750	0.2780	0.2050	0.0220	11.17	6.54	4.82	0.52